NOTES ON

MECHANICAL DRAWING

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MADISON
1912

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CHAPTER I

ORTHOGRAPHIC PROJECTION

1. In Fig. 1 let abc represent the object ABC as it appears when viewed through the plane T from the point S.

The figure abc is the **projection** of the object.

The plane T is the **plane of projection.**

The point S is the **point of sight.**

The lines SA, SB and SC are **projecting lines.**

Each point of the object is projected along its projecting line to the plane of projection. Thus:—

The point A is projected along AS to a.

The point B is projected along BS to b.

The point C is projected along CS to c.

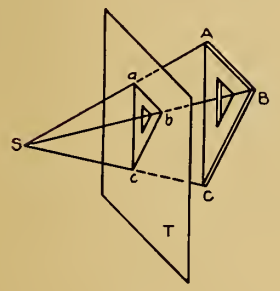


FIG. 1

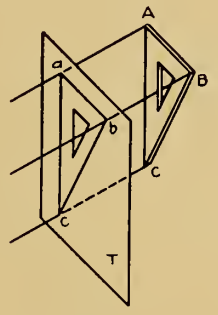


FIG. 2

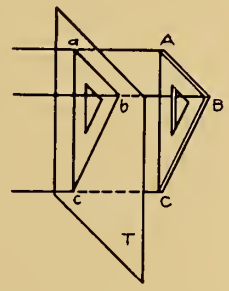


FIG. 3

2. When the point of sight is at a finite distance from the plane of projection, the representation is called a **perspective.** Fig. 1. In perspective the projecting lines converge from the points of the object to the point of sight.

When the point of sight is at an infinite distance from the plane of projection the projecting lines are parallel.

If the projecting lines are parallel to each other and oblique to the plane of projection, the representation is called an **oblique projection.** Fig. 2.

If the projecting lines are parallel to each other, and perpendicular to the plane of projection, the representation is called an **orthographic projection.** Fig. 3.

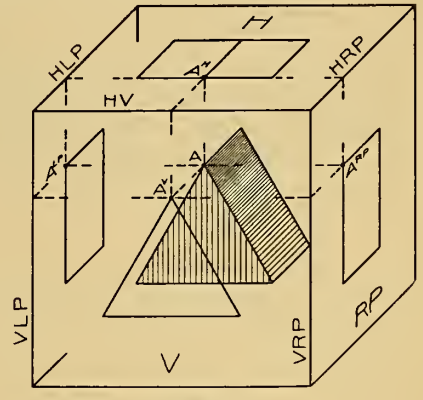


FIG. 4

3. In orthographic projection two or more planes of projection are generally used.

Let Fig. 4 represent a regular triangular prism and its projection on the transparent faces of a hollow cube.

The upper horizontal face of the cube is called the **horizontal plane of projection,** or **H.**

The front face of the cube is called the **vertical plane of projection,** or **V.**

The right side face of the cube is called the **right profile plane of projection,** or **RP.**

The left side face of the cube is called the **left profile plane of projection,** or **LP.**

When only one profile plane is used it is designated as P.

The intersections of these planes are called **ground lines.**

The intersection of H and V is designated as **HV.**

The intersection of V and RP is designated as **VRP.**

The intersection of V and LP is designated as **VLP.**

The intersection of H and RP is designated as **HRP.**

The intersection of H and LP is designated as **HLP.**

When only one profile plane is used its intersections with H and V are designated as HP and VP, respectively.

4. Each point of the object is viewed in a direction perpendicular to each of the planes of projection. Thus, A^H represents the point A as it appears when viewed from above in a direction perpendicular to H. A^V represents the point as it appears when viewed from in front in a direction perpendicular to V. A^{RP} represents the point as it appears when viewed from the right in a direction perpendicular to RP, and A^{LP} represents the point as it appears when viewed from the left in a direction perpendicular to LP.

5. The projection of the object on the horizontal plane is called the **top view, plan,** or **horizontal projection.** That on the vertical plane is called the **front view, front elevation,** or **vertical projection.** The projections on the right and left profile planes are called the **right and left side or end views, right and left side elevations,** or **right and left profile projections.** The bottom and rear views of an object are seldom necessary. The expressions top view, front view, right side view and left side view are preferred. The terms plan, front elevation, side elevation are used in architectural work. In treatises on descriptive geometry the terms horizontal projection, vertical projection and profile projection are employed.

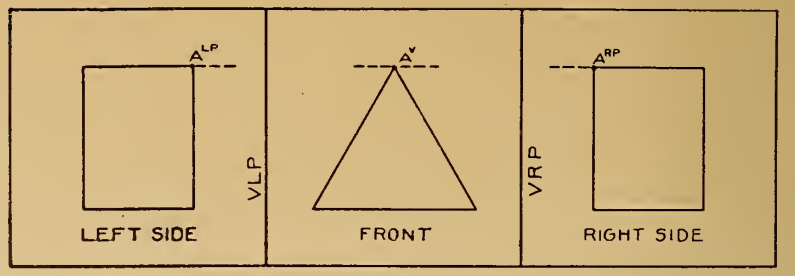


FIG. 5

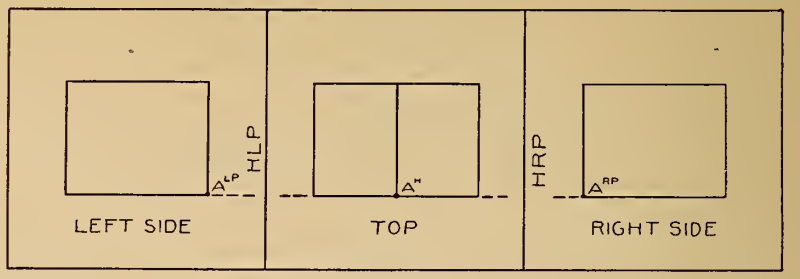


FIG. 6

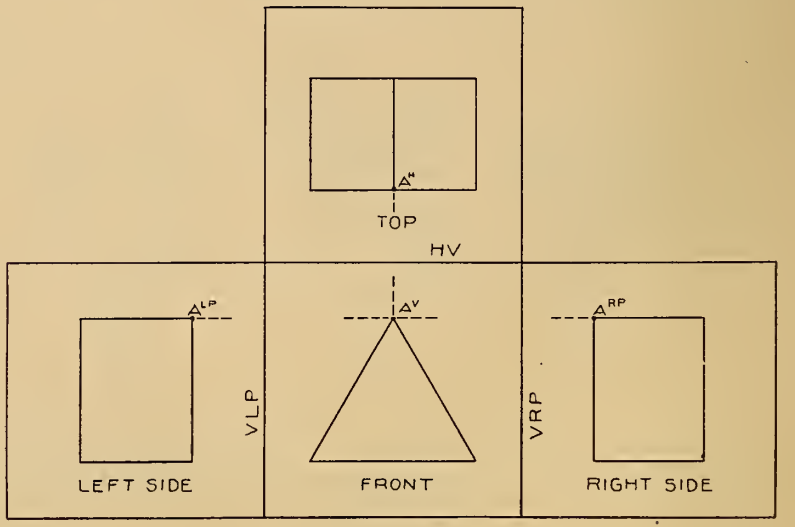


FIG. 7

6. The projecting lines AA^H and AA^V, Fig. 4, determine a plane perpendicular to HV.

The projecting lines AA^V and AA^{RP} or AA^{LP} determine a plane perpendicular to VRP and VLP.

The projecting line AA^H and AA^{RP} or AA^{LP} determine a plane perpendicular to HRP and HLP.

Hence:—A point and its projections on any two of the planes of projection will determine a plane perpendicular to the intersection of those planes.

7. In order to represent the object on a single plane, as a sheet of drawing paper, the planes of projection are revolved into H or V.

8. (*a*) When the front and side views are required the profile planes are folded into V. Fig. 5.

(*b*) When the top and side views are required the profile planes are folded into H. Fig. 6.

(*c*) When the top, front and side views are required the profile planes are revolved into V. Fig. 7.

9. When the profile planes are revolved into the vertical plane the profile projections of any point will remain in a plane perpendicular to VRP or VLP. Thus, A^{RP}, Figure 4, will take the position A^{RP}, Fig. 5, on a horizontal line through A^V.

When the profile planes are revolved into the horizontal plane the profile projections of any point will remain in a plane perpendicular to HRP or HLP. Thus, A^{RP}, Fig. 4, will take the position A^{RP}, Fig. 6, on a horizontal line through A^H.

When H and V are revolved into one plane A^H and A^V will lie in the same perpendicular to HV.

10. Points in space are designated by capital letters A, B, C, etc.; the corresponding horizontal projections by A^H, B^H, C^H, etc.; and the corresponding vertical projections by A^V, B^V, C^V, etc.

11. Solids are limited by surfaces.

Surfaces are limited by lines (edges).

Lines are limited by points (corners).

The projections of a solid will contain the corresponding projections of its limiting surfaces, lines and points.

12. Let Fig. 8 represent a triangular prism and its projections on H and V.

The face ABC, Fig. 8, is parallel to V, and therefore perpendicular to H.

(*a*) Its front view, Figs. 8–9–10. is the same form and size as the face of the prism.

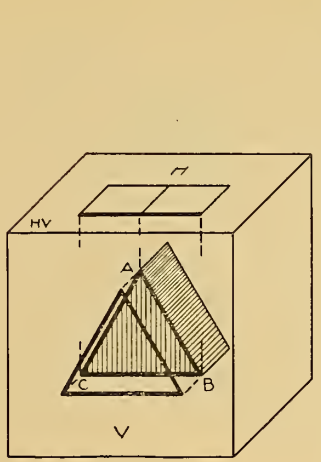


FIG. 8

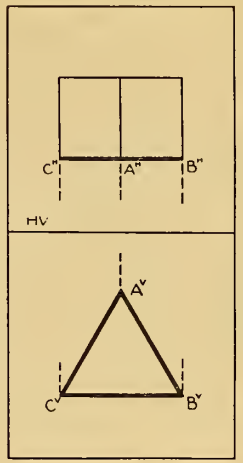


FIG. 9

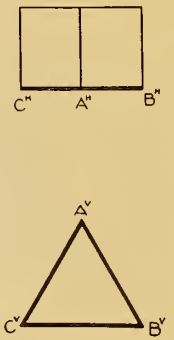


FIG. 10

(*b*) Its top view, Figs. 8–9–10, is a straight line parallel to HV.

Hence, if a plane figure is parallel to V its front view will be a figure of the same form and size as the figure in space, and its top view will be a straight line parallel to HV.

Likewise, if a plane figure is parallel to H, its top view will be a figure of the same form and size as the figure in space, and its front view will be a straight line parallel to HV.

13. Let Fig. 11 represent a triangular pyramid and its projections on H and V.

The face ABFE, Fig. 11, is perpendicular to V and inclined to H and P.

(*a*) Its front view, Figs. 12–13, is a straight line. This line makes a angle with HV equal to the angle the face in space makes with H.

(*b*) Its top view, Figs. 12–13, is a figure which is less than the true size of the face in space.

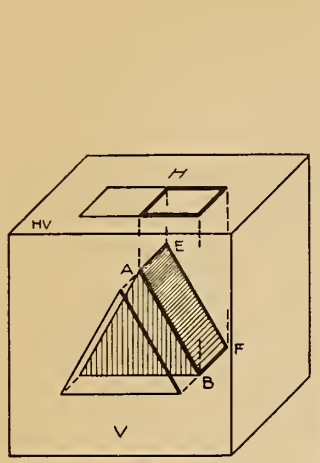


FIG. 11

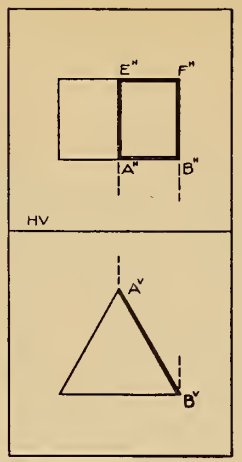


FIG. 12

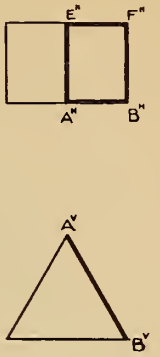


FIG. 13

Hence,—If a plane figure is perpendicular to V and inclined to H, its front view will be a straight line which will make an angle with HV equal to the angle the figure in space makes with H.

The top view will be less than the true size of the figure in space.

Likewise, if a plane figure is perpendicular to H and inclined to V its top view will be a straight line which will make an angle with HV equal to the angle the figure in space makes with V. The front view will be less than the true size of the figure in space.

14. Let Fig. 14 represent a regular triangular prism and its H and V projections.

The edge AE, Fig. 14, is perpendicular to V and therefore parallel to H.

(*a*) Its front view, Figs. 15–16, is a point.

(*b*) Its top view, Figs. 15–16, is a straight line perpendicular to HV and equal in length to AE.

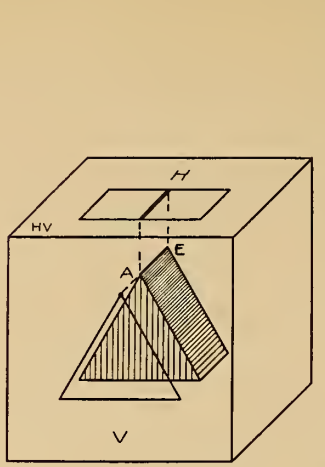


FIG. 14

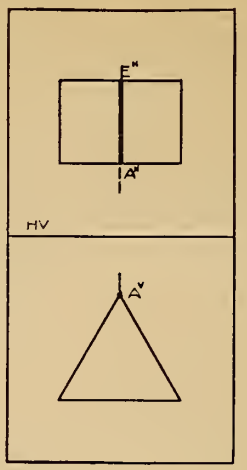


FIG. 15

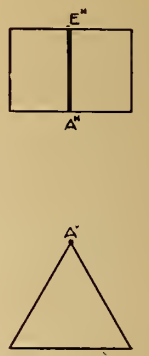


FIG. 16

Hence,—If a straight line is perpendicular to V its front view is a point and its top view is a straight line perpendicular to HV and equal in length to the line in space.

Likewise, if a straight line is perpendicular to H, its top view is a point and its front view is a straight line perpendicluar to HV and equal in length to the line in space.

15. Let Fig. 17 represent a regular triangular prism and its H and V projections.

The edge BC, Fig. 17, is parallel to H and V.

(*a*) Its top and front views, Fig. 17–18–19, are parallel to HV and equal in length to the line in space.

Hence,—If a straight line is parallel to H and V its H and V projections are parallel to HV and equal in length to the line in space.

16. Let Fig. 20 represent a regular triangular prism and its H and V projections.

The edge AC, Fig. 20, is parallel to V and inclined to H and P.

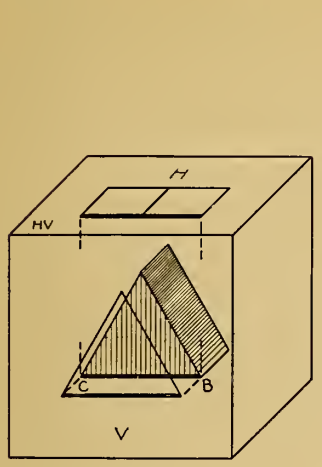


FIG. 17

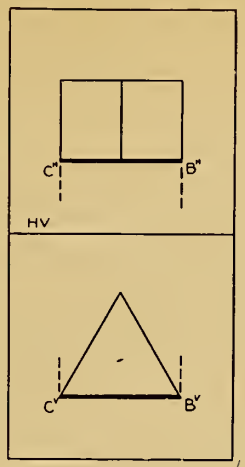


FIG. 18

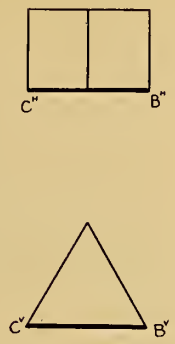


FIG. 19

(*a*) Its front view, Figs. 21–22, is a straight line equal in length to AC. This view makes an angle with HV equal to the angle AC makes with H.

(*b*) Its top view, Figs. 21–22, is a straight line parallel to HV and shorter than the true length of the line.

Hence,—If a straight line is parallel to V and inclined to H, its front view will show the true length, and will make an angle with HV equal to the angle the line in space makes with H. The top view will be parallel to HV and shorter than the true length of the line.

Likewise, if a straight line is parallel to H and inclined to V its top view will be equal to the true length of the line, and will make an angle with HV equal to the angle the line in space makes with V. The front view will be parallel to HV and shorter than the true length of the line.

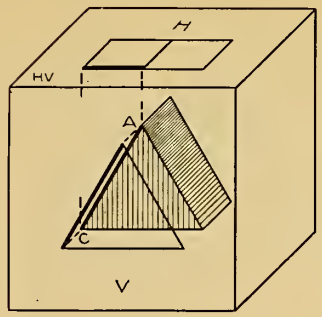


FIG. 20

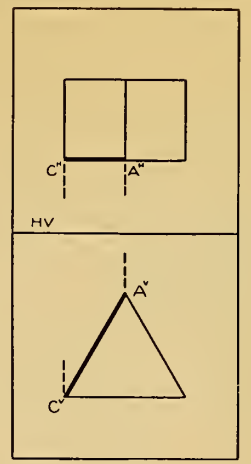


FIG. 21

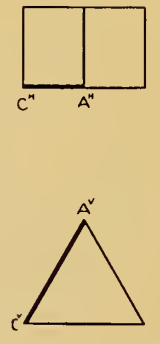


FIG. 22

PROBLEMS

17. To draw the top and and front view of a regular square prism having its base parallel to H and two of its lateral faces parallel to V. Fig. 23.

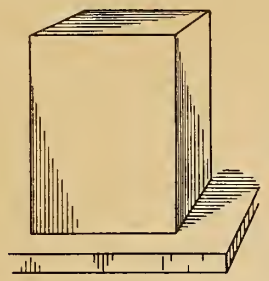


FIG. 23

Since the bases of the prism are parallel to H:

(*a*) Their top view $A^HB^HC^HD^H$, Fig. 24, is the same form and size as the bases in space.

(*b*) Their front views A^VD^V and F^VE^V, Fig. 24, are straight lines parallel to HV.

Since two of the lateral faces are parallel to V:

(*a*) Their front view $A^VD^VE^VF^V$, Fig. 24, is the same form and size as the faces in space.

(*b*) Their top views A^HD^H and B^HC^H are straight lines parallel to HV.

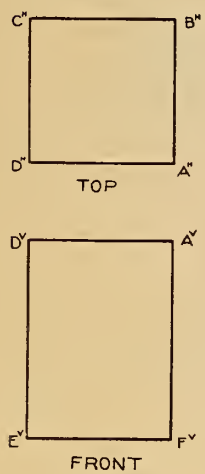


FIG. 24

1. Draw top and right side views of a regular square prism. Bases parallel to H. Two opposite lateral faces perpendicular to P.

2. Draw the front and left side views of a regular square prism. Bases parallel to V. Two opposite lateral faces parallel to P.

3. Draw the front and right side views of a regular square prism. Bases parallel to P. Two opposite lateral faces parallel to V.

4. Draw the left side and top views of a regular square prism. Bases parallel to P. Two opposite lateral faces parallel to H.

18. To draw the front and right side views of a regular hexagonal prism having its bases parallel to P and two of its lateral faces perpendicular to V. Fig. 25.

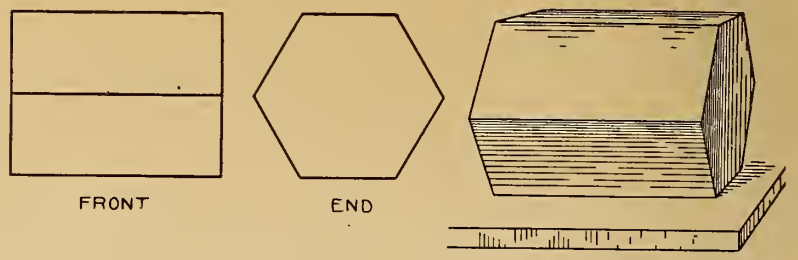


FIG. 26 FIG. 25

Since the bases are parallel to P:

(*a*) Their side view, Fig. 26, is a regular hexagon of the same form and size as the bases in space.

(*b*) Their front views, Fig. 26, are straight lines parallel to VP.

Since two of the lateral faces are perpeudicular to V:

(*a*) Their front and side views, Fig. 26, are straight lines perpendicular to VP.

1. Draw the front and end views of a regular hexagonal psism. Bases parallel to P. Two opposite lateral faces parallel to V.

2. Draw the top and end views of a regular hexagonal prism. Bases parallel to P. Two opposite lateral faces parallel to H.

3 Draw the top and front views of a regular hexagonal prism. Bases parallel to H. Two opposite lateral faces parallel to V.

4. Draw the front and right side views of a regular hexagonal prism. Bases parallel to V. Two opposite lateral faces perpendicular to P.

19. To draw the top and front views of a right circular cylinder. Fig. 27.

Since the bases are parallel to H:

(*a*) Their top view, Fig. 28, is a circle of the same size as the bases of the cylinder.

(*b*) Their front views, Fig. 28 are straight lines parallel to HV.

In viewing the cylinder through the vertical plane, one-half of the curved surface is seen and the other half is hidden. The elements which separate the visible from the invisible portions of the surface are called extreme elements of the cylinder.

1. Draw the front and right side views of a right circular cylinder. Bases parallel to P.

2. Draw the top and front views of a right circular cylinder. Bases parallel to H.

3. Draw the front and left side views of a right circular cylinder. Bases parallel to V.

4. Draw the front and right side views of a right circular cylinder. Bases parallel to V.

20. To draw the top and front views of a regular square prism having its bases parallel to H and two of its lateral faces at an angle of 30° to V. Fig. 29.

Since the bases are parallel to H:

(*a*) Their top view, Fig. 30, is the same form and size as the bases in space.

(*b*) Their front views, Fig. 30, are straight lines parallel to HV.

Since two of the lateral faces make an angle of 30° to V:

(*a*) Their top views, Fig. 30, are straight lines making an angle of 30° to HV.

(*b*) Their front views, Fig. 30, are less than the true size of the face in space.

The edge which is not seen in the front view is shown by a dotted line.

1. Draw the top and front views of a regular square prism. Bases parallel to V. Two opposite lateral faces 30° to H.

2. Draw the front and right end views of a regular square prism. Bases parallel to P. Two opposite lateral faces 60° with V.

3. Draw the left and front end views of a regular square prism. Bases parallel to P. Two opposite lateral faces 30° with V.

4. Draw the front and right side views of a regular square prism. Bases parallel to V. Two opposite lateral faces 60° to P.

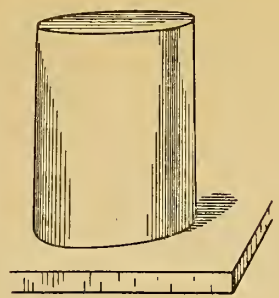


FIG. 27

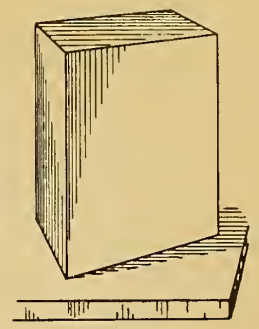
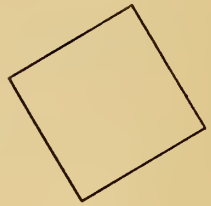


FIG. 29

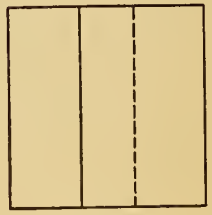
TOP

FRONT

FIG. 28



TOP



FRONT

FIG. 30

21. To draw the top and front views of a regular square pyramid having its base parallel to H and two of the edges of its base parallel to V. Fig. 31.

Since the base is parallel to H:

(*a*) Its top view, Fig. 32, is a square of the same form and size as the base of the pyramid.

(*b*) Its front view, Fig. 32, is a straight line.

Since the two edges of the base are parallel to V:

(*a*) Their top and front views, Fig. 32, are straight lines parallel to HV.

Since the altitude of the pyramid is parallel to V:

(*a*) Its top view is a point.

(*b*) Its front view is a straight line parallel to HV.

1. Draw the top and front views of a regular square pyramid. Base parallel to V. Two opposite edges of the base parallel to H.

2. Draw the front and right side views of a regular square pyramid. Base parallel to V. Two opposite edges of the base parallel to P.

3. Draw the front and left side views of a regular square pyramid. Base parallel to V. Two opposite edges of the base parallel to P.

4. Draw the front and right side views of a regular square pyramid. Base parallel to P. Two opposite edges of the base parallel to V.

22. To draw the top and front views of a regular square pyramid having its base parallel to H and two of the edges of its base at an angle of 30° to V. Fig. 33.

Since the base is parallel to H:

(*a*) Its top view, Fig, 34, is a square of the same form and size as the base of the pyramid.

(*b*) Its front view, Fig. 34, is a straight line parallel to HP.

Since two of the edges of the base are parallel to H and 30° to V:

(*a*) Their top views, Fig. 34, are straight lines making an angle of 30° to HV.

(*b*) Their front view, Fig. 34 is a straight line parallel to HV.

1. Draw the top and front views of a regular square pyramid. Base parallel to V. Two opposite edges of the base 30° to H.

2, Draw the front and right side views of a regular square pyramid. Base parallel to V. Two opposite edges of the base 30° to P.

3. Draw the front and left side views of a regular square pyramid. Base parallel to V. Two opposite edges of the base 60° to P.

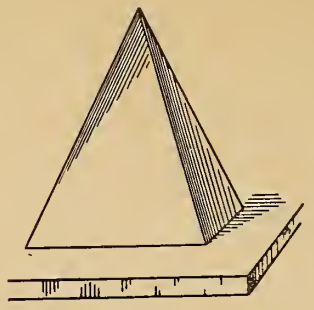


FIG. 31

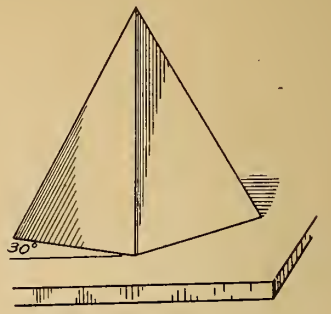
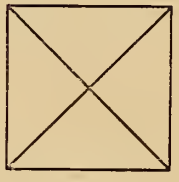


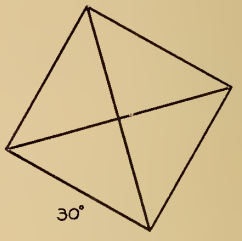
FIG. 33



TOP

FRONT

FIG. 32



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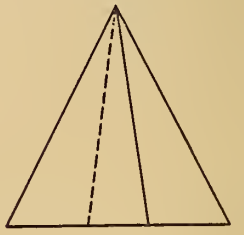


FRONT

FIG. 34

4. Draw the front and right side views of a regular square pyramid. Base parallel to P. Two opposite edges of the base 30° to V.

23. To draw the top and front views of a right circular cone having its base parallel to H. Fig. 35.

Since the base is parallel to H:

(*a*) Its top view, Fig. 36, is a circle of the same form and size as the base of the cone.

(*b*) Its front view, Fig. 36, is a straight line parallel to HV and equal in length to the diameter of the base.

In the front view one-half of the curved surface is seen. The two elements which separate the visible from the invisible portion are called the extreme elements of the cone.

1. Draw the top and front view of a right circular cone. Base parallel to V.

2. Draw the front and right side views of a right circular cone. Base parallel to V.

3. Draw the front and left side views of a right circular cone. Base parallel to V.

4. Draw the front and right side views of a right circular cone. Base parallel to P.

24. To draw the top and front views of a sphere. Fig. 37. A sphere is represented by its contours. These contours are the great circles of the sphere which are parallel to the planes of projection. Since the top and front views are required the great circles which represent the sphere will be parallel to H and V repsectively. Fig. 38.

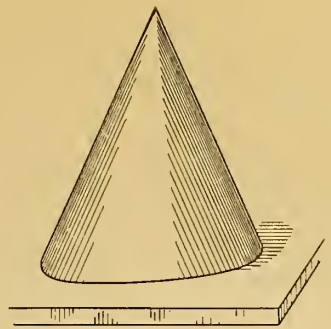


FIG. 35

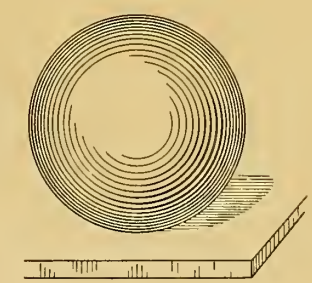
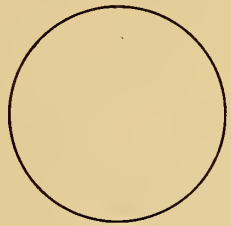


FIG. 37



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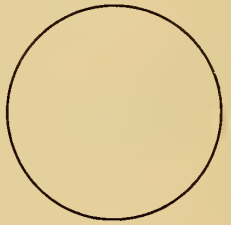

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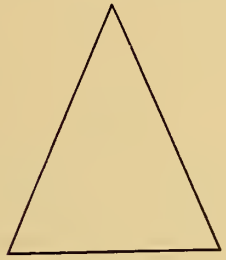
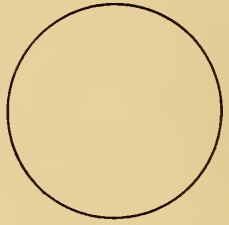


FRONT.

FIG. 36



FRONT

FIG. 38

THE THIRD PLANE OF PROJECTION

25. When more than the vertical and horizontal projections of an object are necessary, or when either of these projections with a third view is required to completely represent the object a third plane of projection is used.

The third plane of projection ordinarily used is perpendicular to both H and V and is called a profile plane or P.

When an object is to be represented on the H, V and P planes each of its points will be viewed in three directions namely perpendicular to H, perpendicular to V and perpendicular to P.

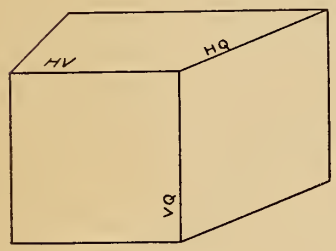


FIG. 39

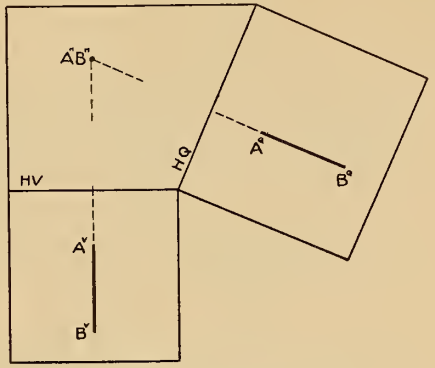


FIG. 40

It is sometimes necessary to draw inclined views of an object situated in a simple position, or the H and V views of an object placed in an inclined position. In such cases planes of projection inclined to one of the principal planes of projection and perpendicular to the other are used. These are called auxiliary planes of projection, or Q.

When an auxiliary plane is perpendicular to H its intersection with H is designated as HQ. Fig. 39. In this case lines perpendicular to H are parallel to V and Q. Such lines will therefore be projected perpendicular to HV and HQ, respectively. Fig. 40. Hence, dimensions perpendicular to HV are equal to dimensions perpendicular to HQ.

When an auxiliary plane is perpendicular to V its intersection with V is designated as VQ. Fig. 41. In this case lines perpendicular to V are parallel to H and Q. Fig. 42. Such lines will be projected perpendicular to HV and VQ respectively. Hence, dimensions perpendicular to HV are equal to dimensions perpendicular to VQ.

26. To draw the top, front and side views of a regular hexagonal prism having its bases parallel to P and two of its lateral faces parallel to H. Fig. 43.

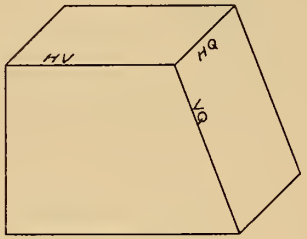


FIG. 41

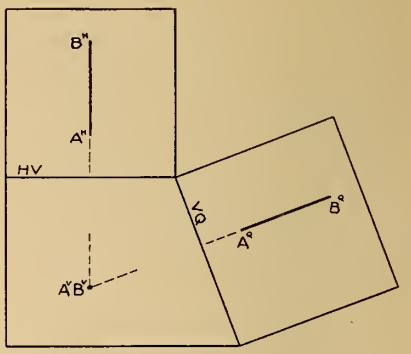


FIG. 42

Since the bases are parallel to P:

(*a*) Their side view, Fig. 44, is a regular hexagon of the same form and size as the bases of the prism.

(*b*) Their front and top views, Fig. 44, are straight lines parallel to VP and HP respectively.

Since two of the lateral faces are parallel to H:

(*a*) Their top view, Fig. 44, is a rectangle of the same form and size as the lateral faces of the prism.

(*b*) Their front and end views, Fig. 44, are straight lines perpendicular to VP.

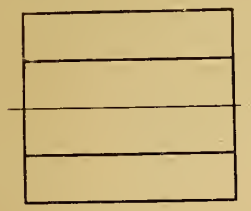
The vertical dimensions on the top view are equal to the horizontal dimensions on the side view.

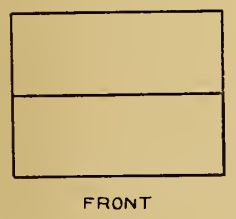
1. Draw the top, front and left side views of a regular hexa-

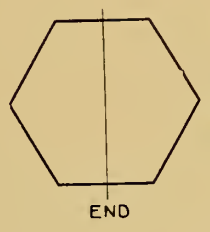
gonal prism. Bases parallel to P. Two opposite lateral faces of the prism parallel to V.

2. Draw the top, front and right side views of a regular hexagonal prism. Bases parallel to V. Two opposite lateral faces parallel to H.

3. Draw the top, front and left side views of a regular hexagonal prism. Bases parallel to H. Two opposite lateral faces parallel to P.







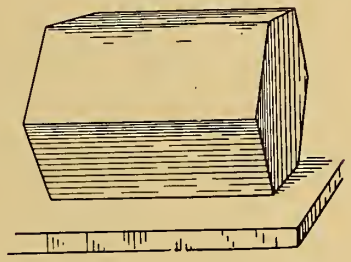


FIG. 44

FIG. 43

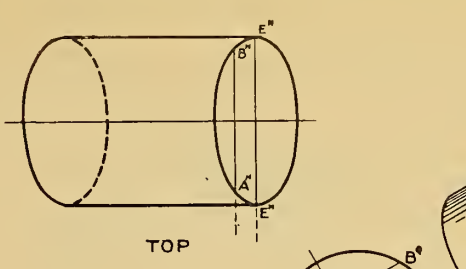
27. To draw the top, front and auxiliary views of a right circular cylinder having its bases parallel to an auxiliary plane. Fig. 45.

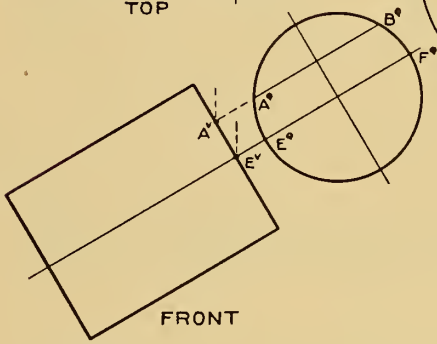
Since the bases are parallel to Q:

(*a*) Their auxiliary view, Fig. 46, is a circle equal in size to the bases of the cylinder.

(*b*) Their front view, Fig. 46, is a straight line equal in length to the diameter of the cylinder. This view is parallel to VQ, and makes an angle with HV equal to the angle Q makes with H.

(*c*) Their top views are ellipses. Chords of the upper base which are perpendicular to HV in the auxiliary view are projected on H in their true lengths. Thus, $A^H B^H = A^Q B^Q$. $E^H F^H = E^Q F^Q$, etc. Points on the top view of the lower base may be found in the same manner.





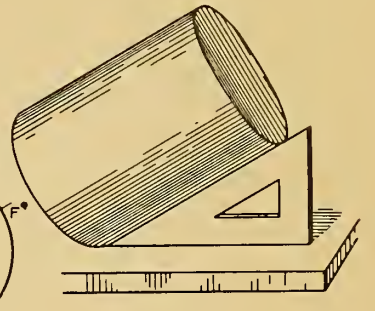


FIG. 46

FIG. 45

28. To draw the top, front and auxiliary views of a right circular cone having its base parallel to an auxiliary plane Q, which is perpendicular to H and inclined to V. Fig. 47.

Since the base is parallel to Q:

(*a*) Its auxiliary view, Fig. 48, is a circle of the same form and size as the base of the cone.

(*b*) Its top view is a straight line equal to the diameter of the base. This view is parallel to HQ and makes an angle with HV equal to the angle Q makes with V.

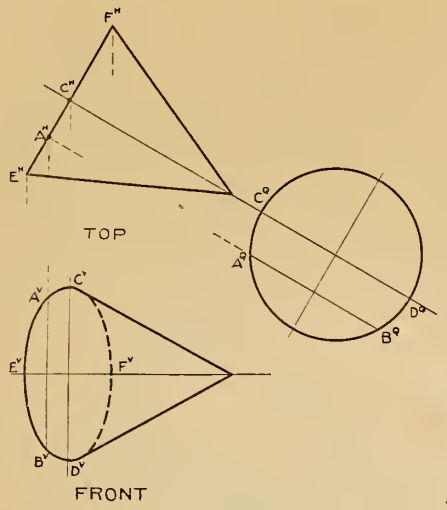


FIG. 48

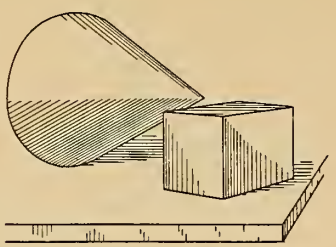


FIG. 47

(*c*) Its front view is an ellipse.

The major axis of the ellipse is the front view of the diameter of the base which is perpendicular to H. C^H is its top view and C^VD^V is its front view. The minor axis of the ellipse is the front view of the diameter of the base which is parallel to H. E^HF^H and E^VF^V are its top and front views respectively. Since the chord AB is perpendicular to H its front view A^VB^V is equal to A^QB^Q. The front view of the vertex is on the minor axis produced. The extreme elements in the front view are tangent to the ellipse. They do not meet the major axis at its extremities.

SECTIONS AND DEVELOPMENTS

29. When an object is cut by an imaginary plane and a portion on either side of the plane is removed, the surface exposed is called a **section.**

If the object is viewed in a direction perpendicular to the section plane and the portion of the object beyond the section plane is shown, the view is called a **sectional view.**

The section of an object is found by finding the points in which its elements or edges pierce the given section plane. Thus in Fig. 49 the edges of the prism pierce the section plane in points which when joined determine the form of the section.

30. If a surface of a solid is rolled into a plane called the plane of development, the portion of the plane touched by the surface will be equal to the given surface and is the **development of the surface.** The development may be started by placing any straight line element in contact with the plane of development. The edges of the base of a right prism will roll out into a straight line perpendicular to the lateral edges. The development of a surface may be rolled into the original form of the surface. Double curved surfaces such as a sphere are not developable.

31. To find the section of a regular square prism, cut by a plane perpendicular to V and inclined to H and P. Show the true size of the section and develop the lateral surface of the prism.

Let Fig. 49 represent the top, front and right side views of the prism; QQ is the front view of the given section plane.

Find the points in which the edges of the prism pierce the section plane.

These piercing points are first located in the front view, since this view of the section plane is a straight line.

The top and side views of the piercing points are projected to the top and side views of the corresponding edges, thus:—

The edge BF pierces the plane QQ at point O, which is projected at O^V in the front view, at O^H in the top view and at O^P in the side view.

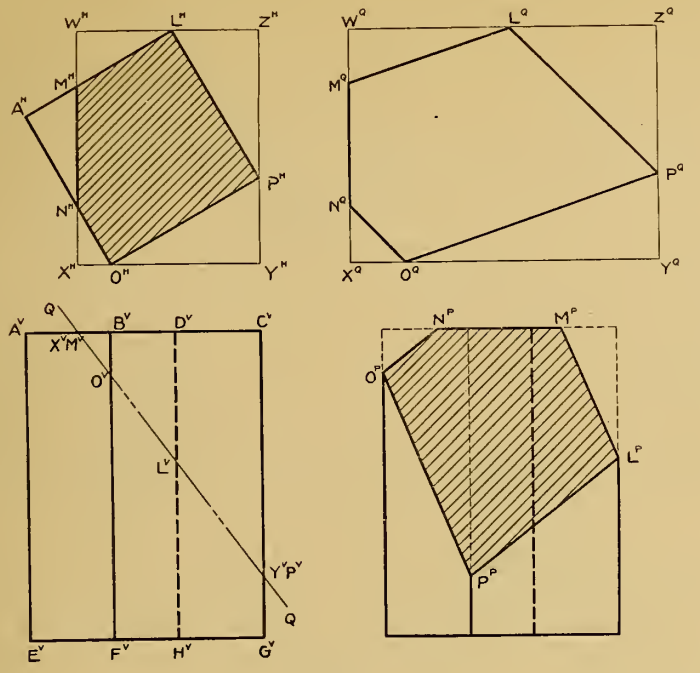


FIG. 49

Straight lines joining the piercing points NOPLMN in order, form the outline of the section.

Since QQ is not parallel to either of the planes of projection the true size of the section is not shown. In order to construct the true size of the section, rectangle WXYZ is drawn in QQ enclosing the section figure. WX and YZ are parallel to H and P and therefore show in their true lengths on H and P. XY and WZ are parallel to V and therefore show in their true lengths on V. In constructing the true size of WXYZ and locating the corners of the section in its sides, true lengths along each line are obtained from the view in which the line shows in its true length.

Lay off $(XY)^Q = (XY)^V$ and $(XW)^Q = (XW)^H$ perpendicular to $(XY)^Q$. Complete the rectangle.

On $(XY)^Q$ lay off $(XO)^Q = (XO)^V$. Locate L^Q in the same manner.

On $(XW)^Q$ lay off $(XM)^Q = (XM)^H$. Locate N^Q and P^Q in the same manner.

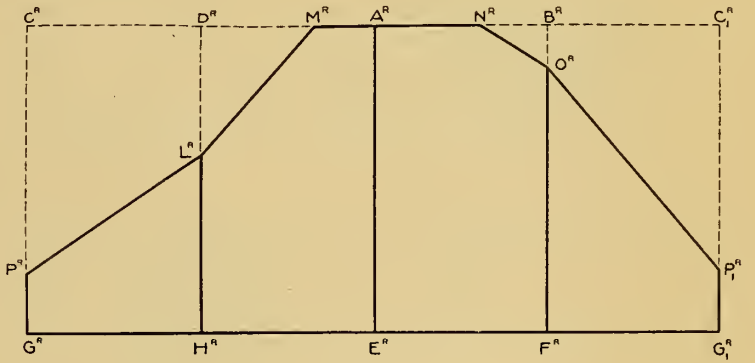


FIG. 50

Lines joining points $(NOPLMN)^Q$ in order, form the true outline of the section.

In the development of the lateral surface of the prism, Fig. 50, the base rolls out into a straight line $(GG_1)^R$.

$(GH)^R$ $(HE)^R$ $(EF)^R$ and $(FG_1)^R$ are each equal to the corresponding side of the base, the true length of which is seen in the top view.

Lay off $(GC)^R = (GC)^V$, the true length of the edge, perpendicular to $(GG_1)^R$. The completed rectangle $(GCC_1G_1)^R$ is the development of the lateral surface of the prism.

To find the outline of the section in the development lay off $(GP)^R = (GP)^V$. Locate L_1^R, O^R, and $P_1{}^R$ in like manner.

Lay off $(AN)^R$ equal to $(AN)^H$ and $(MA)^R$ equal to $(MA)^H$.

Straight lines joining $(PLMANOP_1)^R$ in order, show the outline of the section.

32. To find the section of a right circular cylinder cut by a

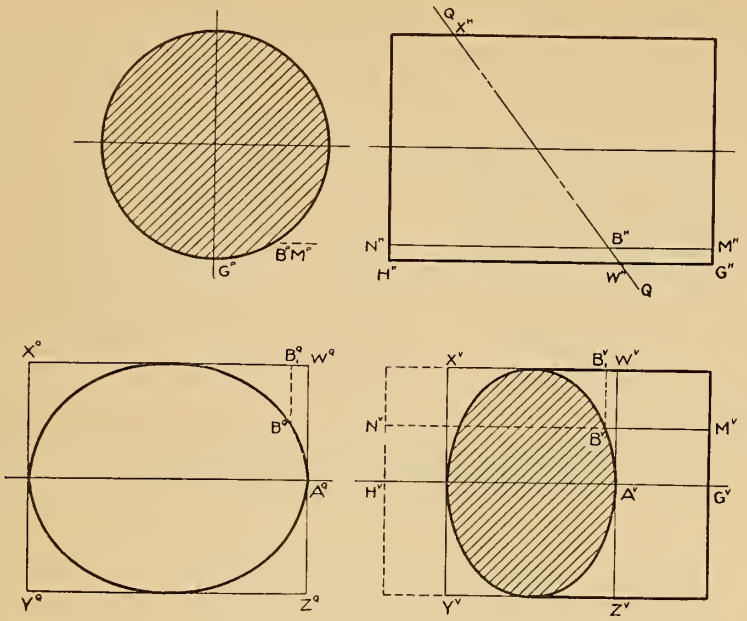


FIG. 51

plane perpendicular to H and inclined to V and P. Show the true size of the section and develop the lateral surface of the cylinder.

Let Fig. 51 represent the top, front and left end views of the given cylinder. QQ is the top view of the given section plane.

Find the points in which the elements of the cylinder pierce the section plane.

These piercing points are first located in the top view, since this view of the section plane is a straight line. The front and side views of the piercing points are projected to the front and side views of the corresponding elements.

Any number of elements may be taken so long as there is a sufficient number to determine the section figure. For convenience in construction twelve are usually chosen at regular intervals.

The element MN pierces the plane QQ at point B which is

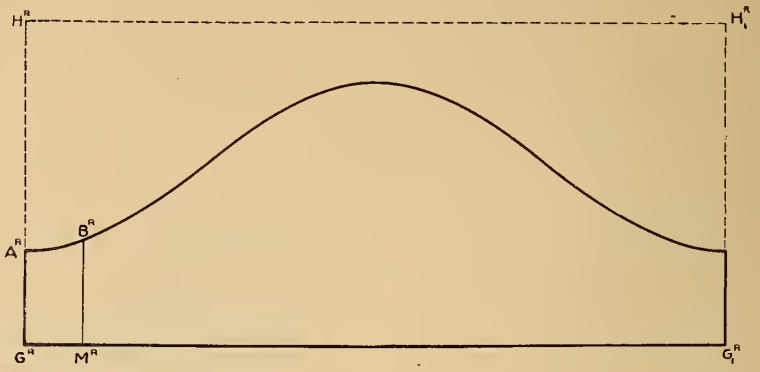


FIG. 52

projected at B^H in the top view, at B^V in the front view and at B^P in the end view.

A smooth curve passing through the piercing points of the chosen elements forms the outline of the section.

Since QQ is not parallel to either of the planes of projection the true size of the section is not shown.

Rectangle WXYZ is drawn in QQ and its true size $(WXYZ)^Q$ constructed as in Art. 31.

Lay off $(WB_1)^Q = (WB)^H$ and $(B_1B)^Q = (B_1B)^V$. All other points are located in the same manner.

A smooth curve passing through the points thus located form the true outline of the section.

In the development of the lateral surface of the cylinder, Fig.

52, the base rolls out into a straight line $(GG_1)^R$. The elements are located by stepping off the chord of the arc between them on $(GG_1)^R$. The elements must be chosen near enough together so that the chord does not differ sensibly from the arc.

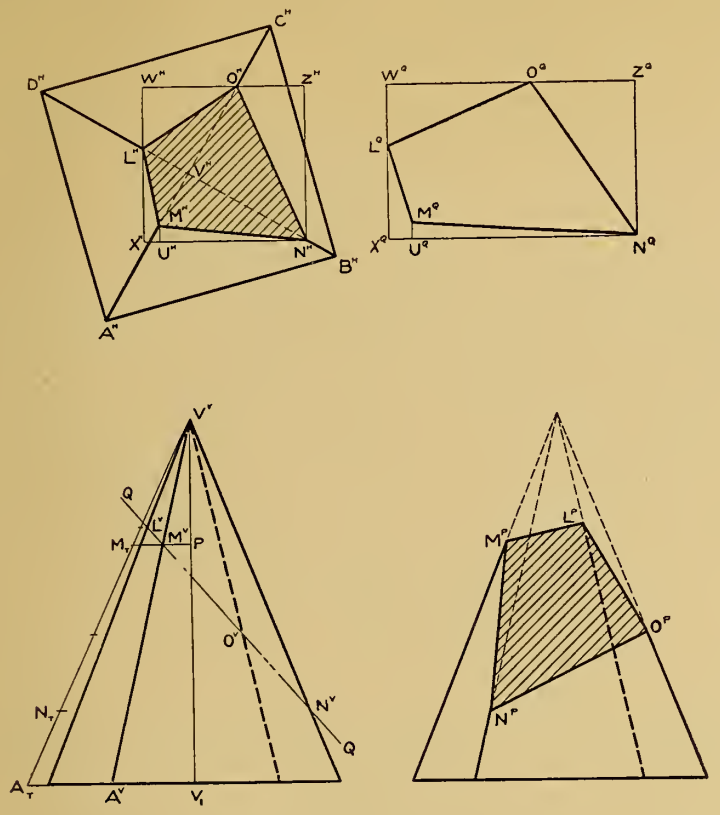


FIG. 53

$(GM)^R = (GM)^P$.

Lay off $(GH)^R = (GH)^H$. the true length of the element perpendicular to $(GG_1)^R$.

The completed rectangle $(GHH_1G_1)^R$ is the development of the lateral surface of the cylinder. To find the outline of the section in the development lay off $(GA)^R = (GA)^H$ and proceed in like manner for the points on the remaining elements.

A smooth curve passing through the points thus located shows the outline of the section.

33. To find the section of a regular square pyramid cut by a plane perpendicular to V and inclined to H and P. Show the true size of the section and develop the lateral surface of the pyramid.

Let Fig. 53 represent the top, front and right side views of the pyramid. QQ is the front view of the given section plane.

Find the points in which the edges of the pyramid pierce the section plane.

These piercing points are first located in the front view, since this view of the section plane is a straight line.

The top and side views of the piercing points are projected to the top and side views of the corresponding edges, thus:—

The edge AV pierces the plane QQ at point M, which is projected at M^V in the front view, M^H in the top view and M^P in the side view.

Straight lines joining the piercing point MNOL in order, form the outline of the section.

Since QQ is not parallel to either plane of projection, the true size of the section is not shown. Rectangle WXNZ is drawn in QQ enclosing the section figure and its true size constructed as in preceding problems.

On $(XW)^Q$ lay off $(XL)^Q = (XL)^H$. On $(WZ)^Q$ lay off $(WO)^Q = (LO)^V$.

M^Q is located by laying off $(XU)^Q = (LM)^V$ on $(XM)^Q$ and $(UM)^Q = (UM)^H$ parallel to $(XW)^Q$.

Lines joining points $(LMNOL)^Q$ in order, form the outline of the true size of the section.

In the development of the lateral surface of the pyramid, Fig. 55, the vertex remains stationary. The development is a series of isoceles triangles, the two equal sides of which are equal in length to the lateral edges and the third side is equal to the side of the base of the pyramid.

In order to construct the development, the true length of the lateral edges of the pyramid must be known. Since none of the lateral edges are parallel to either plane of projection it will be necessary to construct a line showing their true length.

From Fig. 54 it may be seen that the altitude of the pyramid VV_1 and one-half of the diagonal V_1A are the legs of a right tri-triangle of which the edge VA is the hypotenuse. Hence if the true length of VV_1 be laid off perpendicular to the true length of

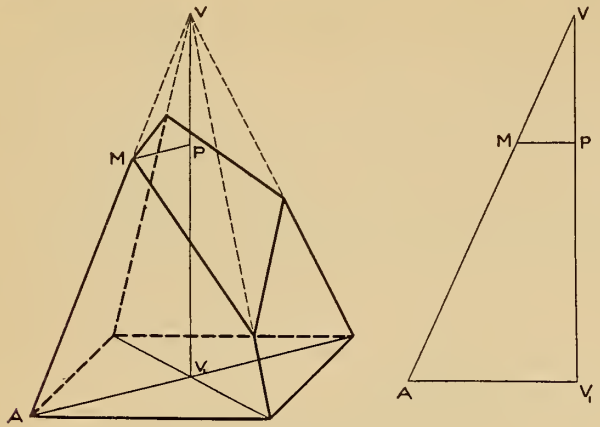


FIG. 54

V_1A and the triangle completed, the hypotenuse of the right triangle thus formed will be the true length of the edge VA.

Point M is located on the true length line by laying off the distance VP along VV_1 and drawing MP parallel to AV_1. In order to save the extra amount of labor and space this construction may be superimposed on one of the orthographic views as in Fig. 53.

Since the edges of the pyramid are equal in length, with V^R as a center, Fig, 55, strike an arc of radius $(VB)^R = V^vA_T$, the true length of the edge as shown in Fig. 53. On this arc strike off chords $(BC)^R$, $(CD)^R$, $(DA)^R$ and $(AB_1)^R$, equal to the corresponding sides of the base.

Lines joining points $(VBCDAB_1V)^R$ in order, form the outline of the development.

To determine the outline of the section in the development lay off $(VN)^R = V^vN_T$, the true length of VN. Locate points $(OLMN_1)^R$ in like manner.

Lines joining the points $(NOLMN_1)^R$ in order, form the outline of the section in the development.

34. To find the section of a right circular cone, cut by a plane

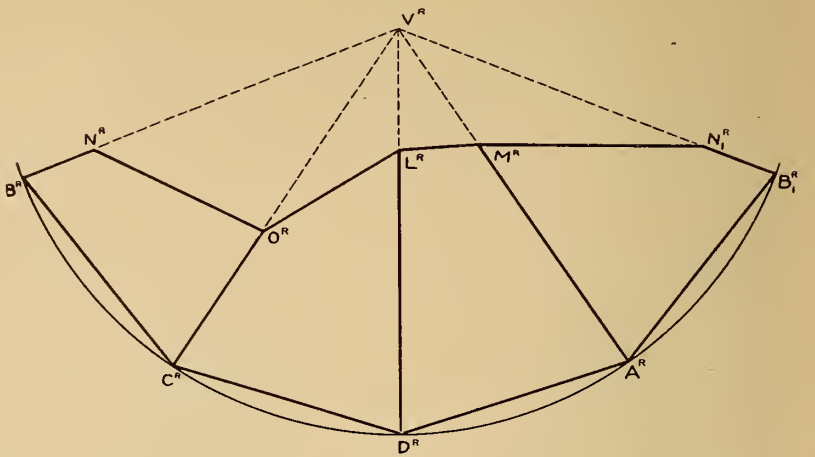


FIG. 55

perpendicular to V and inclined to H and P. Show the true size of the section and develop the lateral surface of the cone.

Let Fig. 56 represent the top, front and right side views of the cone. QQ is the front view of the given section plane.

Find the points in which the elements of the cone pierce the section plane.

These piercing points are first located in the front view, since this view of the section plane is a straight line.

The top and side views of the piercing points are projected to the top and side views of the corresponding elements, thus:—

VN pierces the plane QQ at point C, which is projected at C^V in the front view, at C^H in the top view and at C^P in the side view.

Any number of elements may be taken so long as there is a sufficient number to determine the section figure. For convenience in construction twelve are usually chosen at regular intervals.

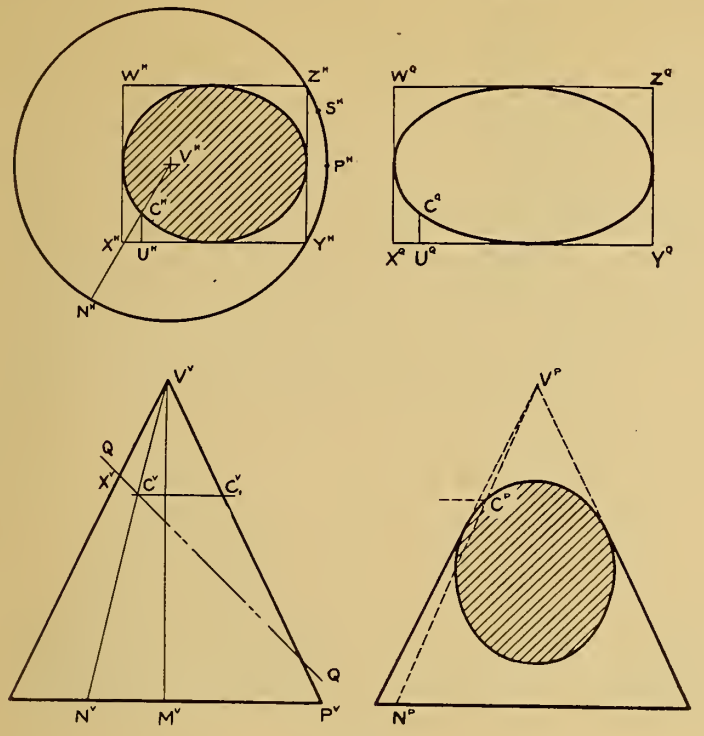


FIG. 56

A smooth curve passing through the piercing points of the chosen elements form the outline of the section.

Rectangle WXYZ is drawn in QQ and its true size $(WXYZ)^Q$ constructed as in the preceding problems.

Lay off $(XU)^Q = (XC)^V$ and $(UC)^Q = (UC)^H$. All other points are located in the same manner.

A smooth curve passing through the points thus plotted forms the true outline of the section, which is an ellipse.

Since the elements of a right circular cone are all equal in length, the base rolls out into an arc of radius equal to the length of the elements. The true length of the elements of the cone is shown in $(VP)^V$, since VP is parallel to V.

Strike an arc of radius $(PV)^R = (VP)^V$. Fig. 57. On this

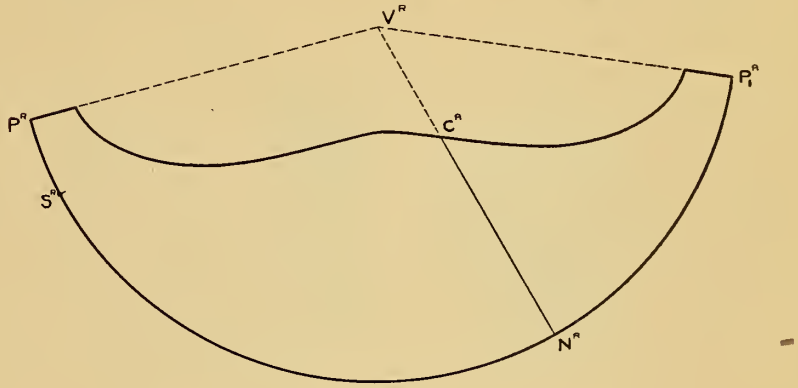


FIG. 57

arc step off $(PS)^R$ equal to chord $(PS)^H$. Continue this process until the periphery of the base is laid off along the arc. The angle which the chord subtends must be small enough that the chord does not differ sensibly from the arc.

Since all the elements of the cone are equal in length, the right triangle formed by the altitude, radius of the base and any element is equal to triangle $(VMP)^V$. Hence to find the true length of VC it is only necessary to draw a horizontal line through C^V until it strikes $(VP)^V$. (See Art. 33). $(VC_1)^V$ is the true length of VC.

On $(VN)^R$ lay off $(VC)^R = (VC_1)^V$. A smooth curve passing through the points thus determined forms the outline of the section.

35. To find the section of a right circular cone cut by a plane perpendicular to H and inclined to V and P. Show the true size of the section and develop the lateral surface of the cone.

Let Fig. 58 represent the top, front and left side views of the cone. QQ is the top view of the section plane.

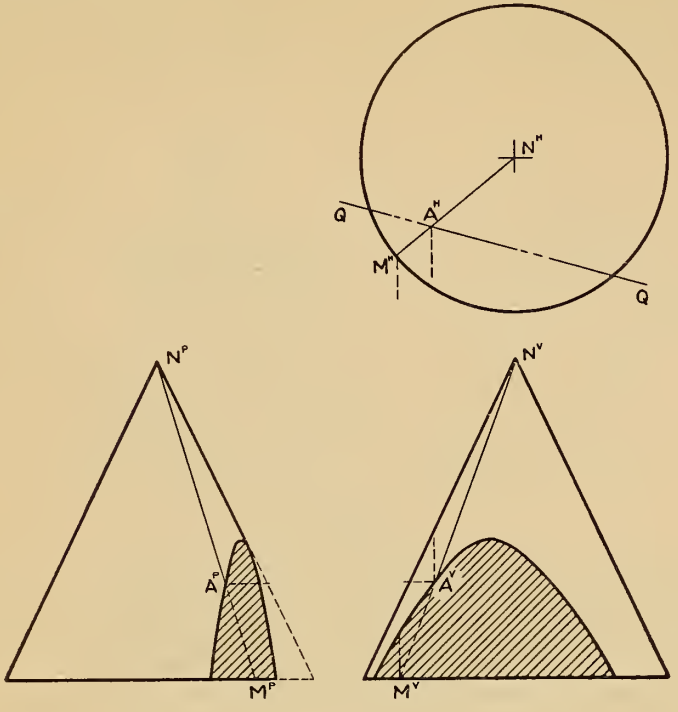


FIG. 58

Find the points in which the elements of the cone pierce the section plane.

These points are first located in the top view, since this view of the section plane is a straight line.

The general principles involved in the solution of the problems are identical with those of the preceding problems.

The section curve is hyperbola.

36. To find the seetion of a right circular cone cut by a plane perpendicular to V and parallel to an element of the cone. Show the trne size of the section and develop the lateral surface of the cone. FIG. 59.

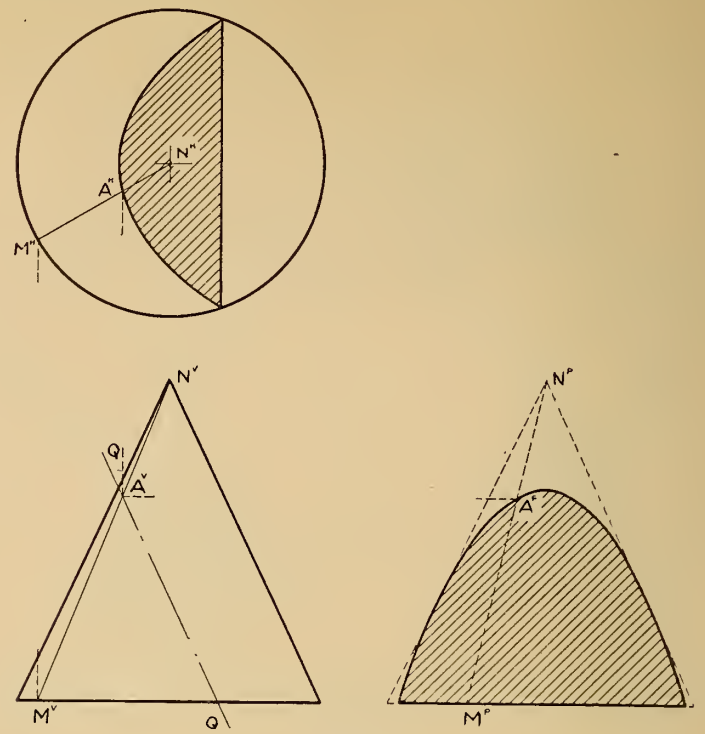


FIG. 59

The method of procedure is the same as for problem in Art. 34.

The section curve is a parabola.

37. To find the section of a sphere cut by a plane perpendicular to H and inclined to V and P. Show the true size of the section.

Let Fig. 60 represent the top, front and right side views of the sphere. QQ is the top view of the given section plane.

Find the points in which a series of circles on the surface of the sphere pierce the section plane.

These circles are taken parallel to one plane of projection and therefore show as true circles on that plane, and as straight lines on the other planes of projection.

The piercing points are first located in the top view, since the top view of the section plane is a straight line. The front and side views of the piercing points are projected to the front and side views of the corresponding circles.

Circle SX pierces QQ at B, which is projected in the top view at B^H, in the front view at B^V and in the side view at B^P.

A smooth curve joining the piercing points of all the circles forms the outline of the section.

The true size of the section is a circle of diameter $(AE)^H$, the chord cut from the great circle by QQ.

The surface of the sphere cannot be developed.

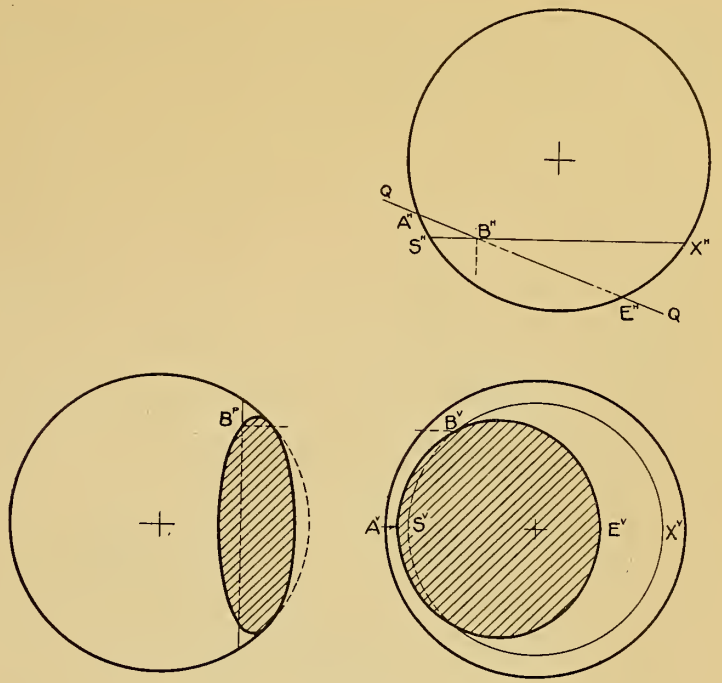


FIG. 60

INTERSECTIONS

38. When two solids intersect, the line common to the surfaces of both solds is called the line of intersection of the two solids.

General Problem. To find the line of intersection of any two solids.

General Method. Find the points in which the elements or edges pierce the given surfaces.

39. To find the line of intersection of two square prisms and develop their lateral surfaces showing the line of intersection.

Let Fig. 61 represent the front, top and side views of the two square prisms.

The points in which the edges of the horizontal prism pierce the faces of the vertical prism are first located in the top view, since in this view the lateral faces of the vertical prism are straight lines, thus:—

IM pierces the face at AB at M, which is projected in the top view at M^H, in the front view at M^V, and in the side view at M^P on the corresponding views of the edge IM.

M^P is best located by drawing the side view of the element in which IM pierces the face AB.

The piercing points of the remaining edges of the horizontal prism are located in a similar manner.

The points in which AE the edge of the vertical prism pierces

the faces of the horizontal prism are first located in the front view, since in this view the lateral faces of the horizontal prism are represented by straight lines, thus:

AE pierces face OL at R which is projected on the front view

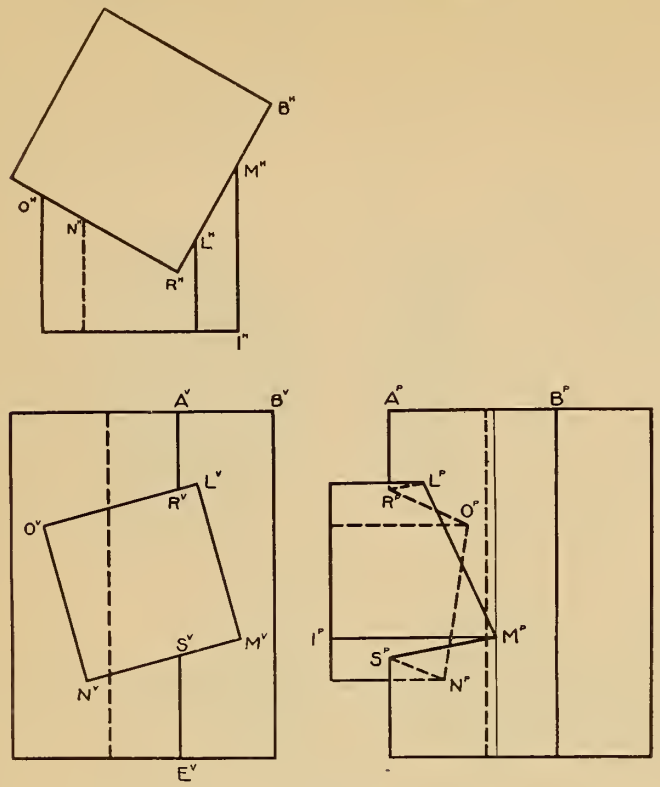


FIG. 61

at R^V, in the top view at R^H, and in the side view at R^P, on the corresponding views of the edge AE. The projections of S are located in a similar manner.

Lines joining points LMSNORL in order, form the line of intersection.

The lateral surfaces are developed according to the principle of Art. 31.

40. To find the line of intersection of a right triangular prism and a cylinder, and develop their lateral surfaces showing the line of intersection.

Let Fig. 62 represent the top, front and side views of the cylinder and prism.

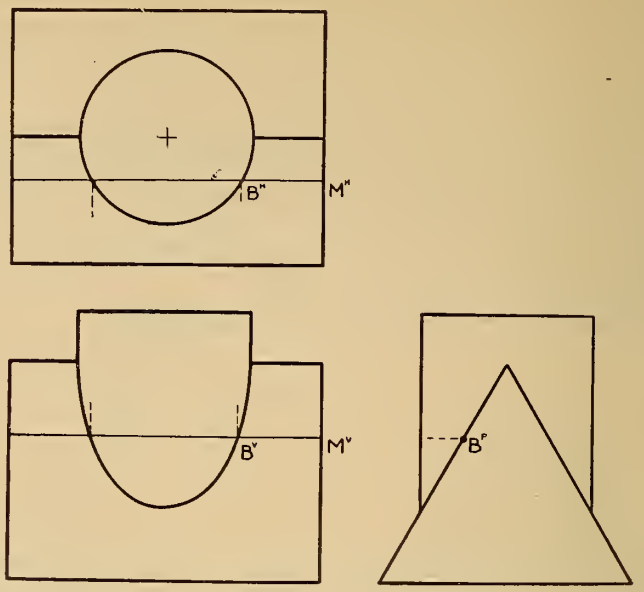


FIG. 62

Assuming elements in the faces of the triangular prism, the points in which they pierce the surface of the cylinder are first seen in the top view where the lateral surface of the cylinder appears as a circle, thus:

BM pierces the cylindrial surface at B, which is projected in the top view at B^H, in the front view at B^V and in the side view at B^P. Any number of elements may be taken so long as there are enough to clearly determine the intersection line, which in

this case is a curve drawn through the common points on the two surfaces located as above.

The lateral surfaces are developed according to the principles of Arts. 31 and 32.

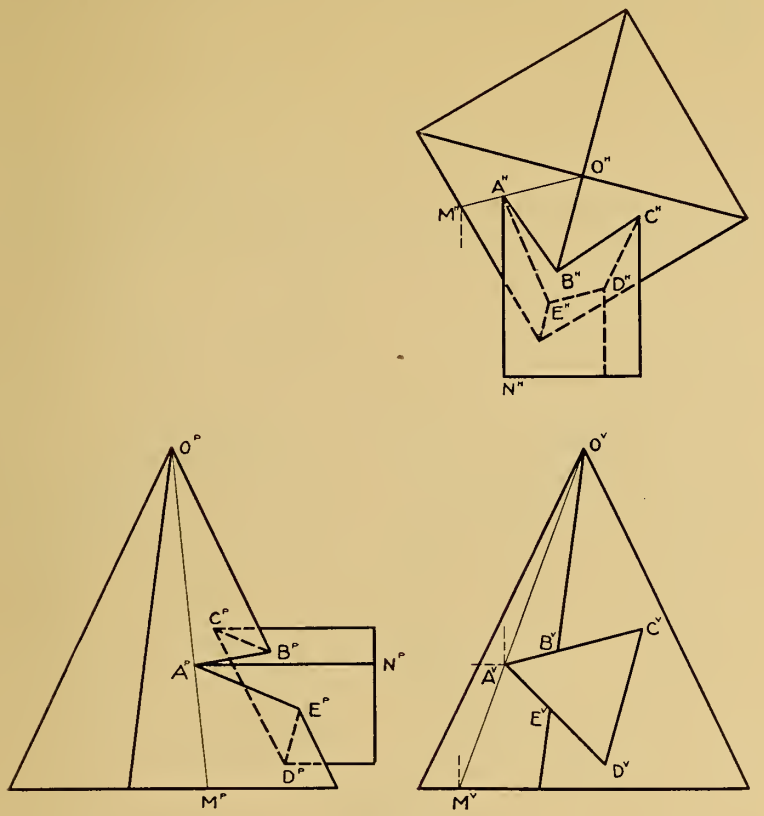


FIG. 63

41, To find the line of intersection of a right square pyramid and a right triangular prism, and develop the lateral surfaces showing the line of intersection.

Let Fig. 63 represent the top, front and left side views of the pyramid and prism.

Since the lateral faces of the pyramid are not seen as straight lines in either view, the points in which the elements and edges of the pyramid pierce the surface of the prism are found. These piercing points are first located in the front view, since this view of the lateral surface of the prism consists of straight lines.

The edge OE of the pypamid pierces the surface of the prism at B which is projected at B^V in the front view, at B^H in the top view and at B^P in the side view on the corresponding projection of OE.

Elements may be taken at random in the faces of the pyramid and the piercing points found, but since the line of intersection will consist of a series of straight lines, only the points where the lines join need be found. Hence, the elements are chosen which intersect the edges of the prism.

The front view M^VO^V of the element MO is drawn through A^V. A^H is on the top view, and A^P on the side view of OM.

The projections of points C and D are similarly located.

Straight lines joining the points BAEDCB in order, from the line of intersection.

The lateral surface of the pyramid is developed according to Art. 33, and that of the prism according to Art. 31.

42. To find the intersection of a right circular cone and a right circular cylinder, and develop the lateral surfaces showing the line of intersection.

Let Fig. 64 represent the top, front and right side views of the cone and cylinder.

Since the lateral surface of the cone is not seen as a line in either view, the points in which the elements of the cone pierce the surface of the cylinder are found. These piercing points are first located in the top view, since that view of the lateral suface of the cylinder is a circle.

The element O M, of the cone pierces the surface of the cylinder at A, which is projected in the top view at A^H, in the front view at $A^V$and in the side view at A^P on the corresponding projections at OM.

Elements may be taken at random in the surface of the cone

and their piercing points found, but for convenience twelve are usually chosen at regular intervals and additional elements put in where it is desirable to locate other points. For instance B

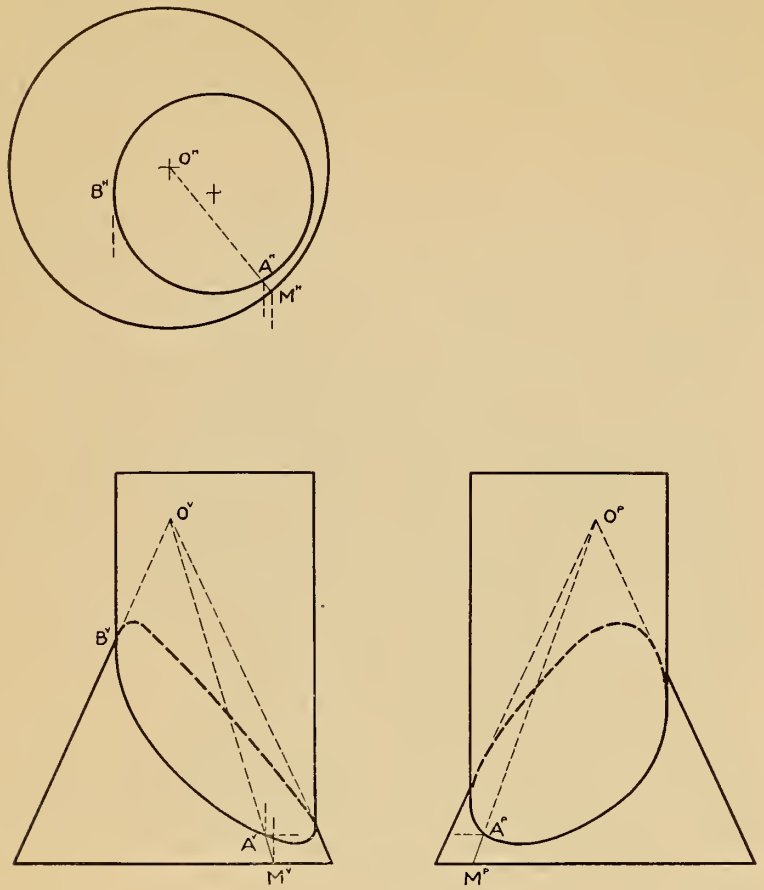


FIG. 64

the point in which the extreme element of the cylinder, in the front view, pierces the cone is an important point and should be located as above.

A smooth curve passing through the points located forms the line of intersection.

The lateral surface of the cone is developed according to Art. 34, and that of the cylinder according to Art. 32.

43. To find the line of intersection of a sphere and a right circular cylinder.

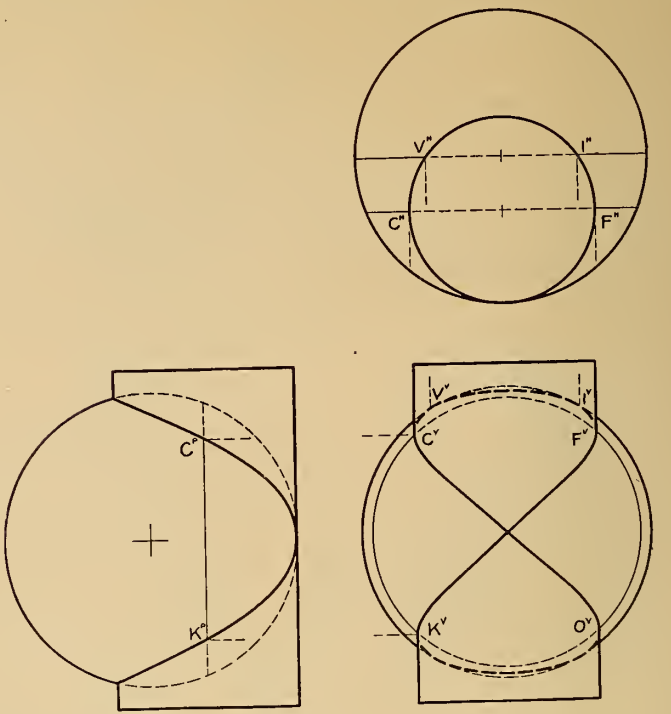


FIG. 65

Let Fig. 65 represent the top, front and left side views of the sphere and cylinder.

Since only the surface of the cylinder is seen as a line, a series of circles are taken on the surface of the sphere and the points in which they pierce the surface of the cylinder located. These

piercing points are found first in the top view, since this view of the cylinder is a circle.

The circle CFOK pierces the surface of the cylinder at C which is projected at C^H in the top view, at C^V in the front view and at C^P in the side view on the corresponding views of the circles CFOK. The projection of points FOK in which circle CFOK also pierces the cylinder are located in a similar manner.

Circles on the sphere may be chosen at random so long as planes are parallel to the elements of the cylinder and also to one of the planes of projection.

Since two circles at eqnal distances on opposite sides of a great circle have the same diameter, the number of circles drawn in one view may be reduced, thereby simplifying the construction.

Care should be taken to locate critical points, for instance the points V and I, on the great circle, which are the points of tangency between the great circle and the line of intersection in the front view.

A smooth curve passing through the points located as above forms the line of intersection.

The lateral surface of the cylinder is developed according to Art. 32. The surface of the sphere is incapable of exact development.

CHAPTER 2

FREEHAND LETTERING

UPRIGHT SINGLE STROKE GOTHIC CAPITALS AND NUMERALS

44. Elements of Letters and Numerals. The Gothic letters and figures are composed of either straight lines, ellipses, or combinations of the two. The straight lines are vertical, horizontal or oblique. For example the capitals H, T, L and others are composed of vertical and horizontal parts, the N, A, K and others are composed of inclined parts combined with either horizontal or vertical parts, while the V, W and X are composed of inclined parts only. The elliptical curves of the letters and numerals have vertical axes. These curves are tangent to the horizontal guide lines which limit the height of the letter.

45. General Proportions. In general letters having distinct upper and lower parts should have the upper part smaller than the lower. *Intermediate horizontal lines* should be placed slightly above the middle, except in the letter A where the horizontal part is one-third the height of the letter above the lower guide line.

46. Quality of Line. All strokes should be made the same width. A pen should be selected that will produce strokes of uniform width in any direction. *A slight uniform pressure* should be brought to bear on the pen, not enough to spread the nibs. The strokes should be made with a slow steady motion. Rapid strokes often produce a cleaner line at first, but with the result that the pen cannot be controlled to form the strokes correctly. At first attention should be given to the form and direction of the strokes and the proportions of the letters. Ability to produce clean, sharp strokes will be acquired by practice. The amount of ink carried in the pen is important. Too little ink makes it difficult to start the strokes. A stroke should not be started until the ink is seen on the paper or tracing cloth. The beginning and end of each stroke should be blunt. The pen should not be lifted from the drawing surface too quickly when the end of a stroke is reached. Too much ink in the pen will often cause blotting. Care should be taken to keep angles and intersections clean and sharp. It will be found that often an unsteady hand can make fair lines after a little practice. The pen should be tried frequently on a surface similar to the surface upon which the lettering is to be done. Short practice strokes about three-sixteenths of an inch in length will bring the ink to the end of the pen and will determine the kind of line the pen will make.

47. Vertical Strokes. These strokes should be made *exactly vertical*. A slight deviation from the vertical is very noticeable. All vertical strokes are made downward. Fig. 66. The vertical

FIG. 66

strokes are started on the upper guide line. In making these strokes the aim should be to reach a point directly under the starting point. As most of the letters have vertical strokes the manner of making them should be thoroughly fixed in the mind of every student. A tendency to slope the strokes forward, as

in inclined lettering, may be counteracted by attempting to finish the strokes slightly to the right of their starting points.

48. Horizontal Strokes. Horizontal strokes are drawn from left to right. Horizontal strokes are drawn on or parallel to the guide lines. Fig. 67.

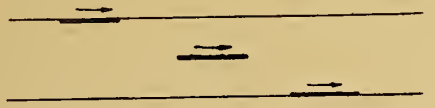


FIG. 67

49. Inclined Strokes. The inclined strokes are made downward and to the right or left. In making inclined strokes the horizontal distances from the beginning of the stroke to the vertical line through the end of the stroke is estimated. Usually these horizontal distances have a known relation to the width of the letters. For example, in making the inclined stroke on the left side of the A the horizontal distance a, Fig. 68, is estimated. In this letter the distance a is equal to one-half the width of the letter. The second stroke ends the same distance to the right of the vertical center line of the letter.

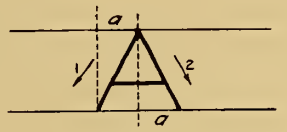


FIG. 68

50. Curved Strokes. The curved strokes are parts of ellipses. The greater part of each curved stroke should be drawn downward or to the right. Avoid moving the pen upward or to the left wherever possible. The distances the curved strokes extend to the right or the left of their initial points is usually determined by the width of the letters. For example, the stroke forming the left side of the O is started on the upper guide line and curves to the left a distance equal to one-half the width of the letter. The horizontal distance a, Fig. 69, is estimated.

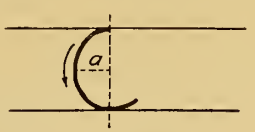


FIG. 69

51. Parallel Inclined Strokes. When two or more inclined strokes in the same letter are parallel their direction is determined by the direction of the first stroke. The direction of the first of the parallel strokes should be carefully estimated.

52. Vertical Center Lines. Some letters or parts of letters are symmetrical with reference to vertical center lines. In such cases the center lines need not be drawn, but their position should be in mind when the symmetrical strokes are made.

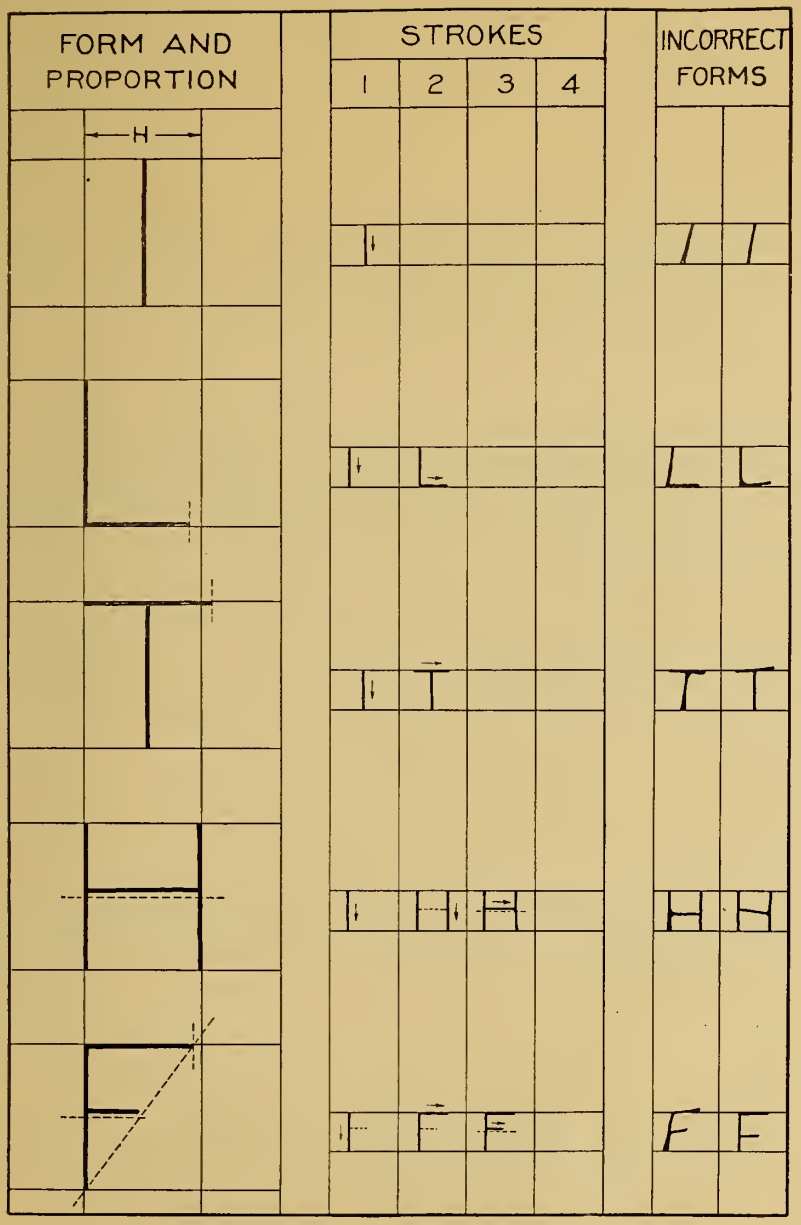
53. Height of Letters. All strokes except the short straight stroke in the Q should be made within the guide lines. Upper horizontal strokes should have their upper edges on the upper guide line. Lower horizontal strokes should have their lower edges on the lower guide line. The upper and lower guide lines should always be drawn for the capital letters.

54. Width of Letters and Numerals. For small single stroke Gothic letters the width of the H may be taken as four-fifths its height. The width of the H is taken as a standard. The E B N R S U and Z are the same width as the H. The C D G K O Q T V and Y are a little wider. The width the of A X and M is equal to their height. Notice that when the height and width of a letter are equal the height appears greater. The letter W is the widest letter of the alphabet, its width being about one and three-quarter times the width of the H. The F P and L are slightly narrower than the H. The J is a narrow letter about four-fifths the width of the H. The I is the width of a single vertical stroke. The 4 is the only numeral that is as wide as the H. The 2 3 5 6 8 9 and 0 are narrower than the H.

The 7 is the same width as the J. The 1 is a single vertical stroke. When the standard of width is small compared with the height, the letters and numerals are said to be *condensed* and when greater they are *extended*. Until the normal widths of the letters can be accurately estimated, a strip of paper with the width of the H marked on its lower edge will be found convenient. The strip may be placed over each letter during practice.

55. Spacing. The spaces between letters should appear as nearly equal as the forms of the letters will permit. The spaces between the words and between lines of words should be sufficient to allow the words to stand out plainly. One and a half times the width of the capital H will usually be sufficient between words. Some strokes are difficult to make on account of the fact that the spacing as well as their form and direction must be kept in mind at the same time. To illustrate, the left side of the O is formed by a stroke which begins on the upper guide line and curves to the left a distance which will leave the proper space between it and the right hand side of the previous letter. This stroke is formed and the letter spaced in one operation. When strokes of this type are made their initial points should be carefully located.

56. Position of Hand, Arm and Body. The pen holder should be held firmly as in writing. The forearm should rest upon the drawing board or the drawing table. Always *stand when doing freehand lettering*. The fingers of the left hand should be placed slightly to the left of the letters to be formed. A slight pressure of the left hand against the paper will place the body in a balanced position. This pressure will assist the right hand in securing the proper pressure of the pen on the paper. In making vertical strokes the forearm should be almost parallel to the strokes to be made, In making horizontal strokes the pen holder should be rolled slightly so as to secure lines of the same width as the vertical lines. In making inclined strokes the forearm should be shifted to a position almost parallel to the direction of the strokes. The curved strokes are made with a combined finger and wrist motion. After some skill is acquired it will be found possible to make most of the strokes without changing the direction of the forearm.



57.

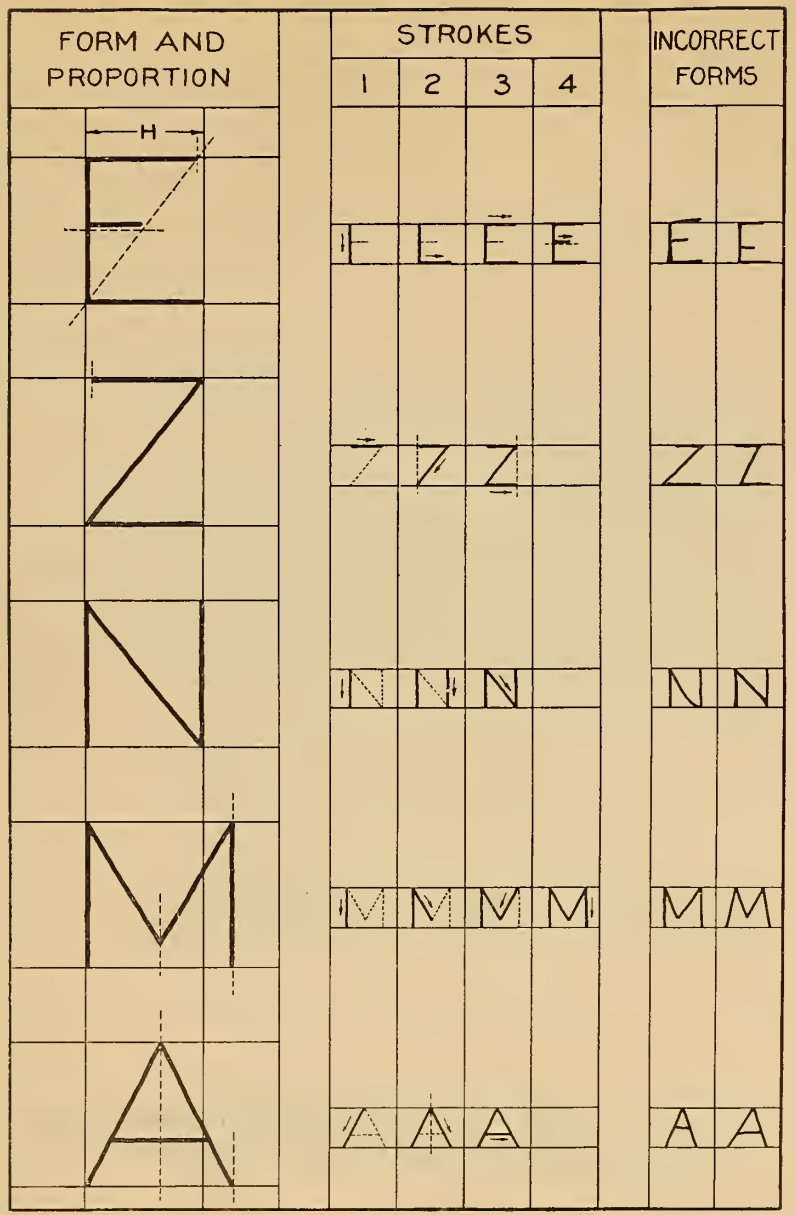
A single vertical stroke.

Narrower than the H.

Slightly wider than the H.

The horizontal bar is slightly above mid-height.

Narrower than the H. Intermediate horizontal stroke slightly above mid-height and equal in length to one-half the width of the letter.



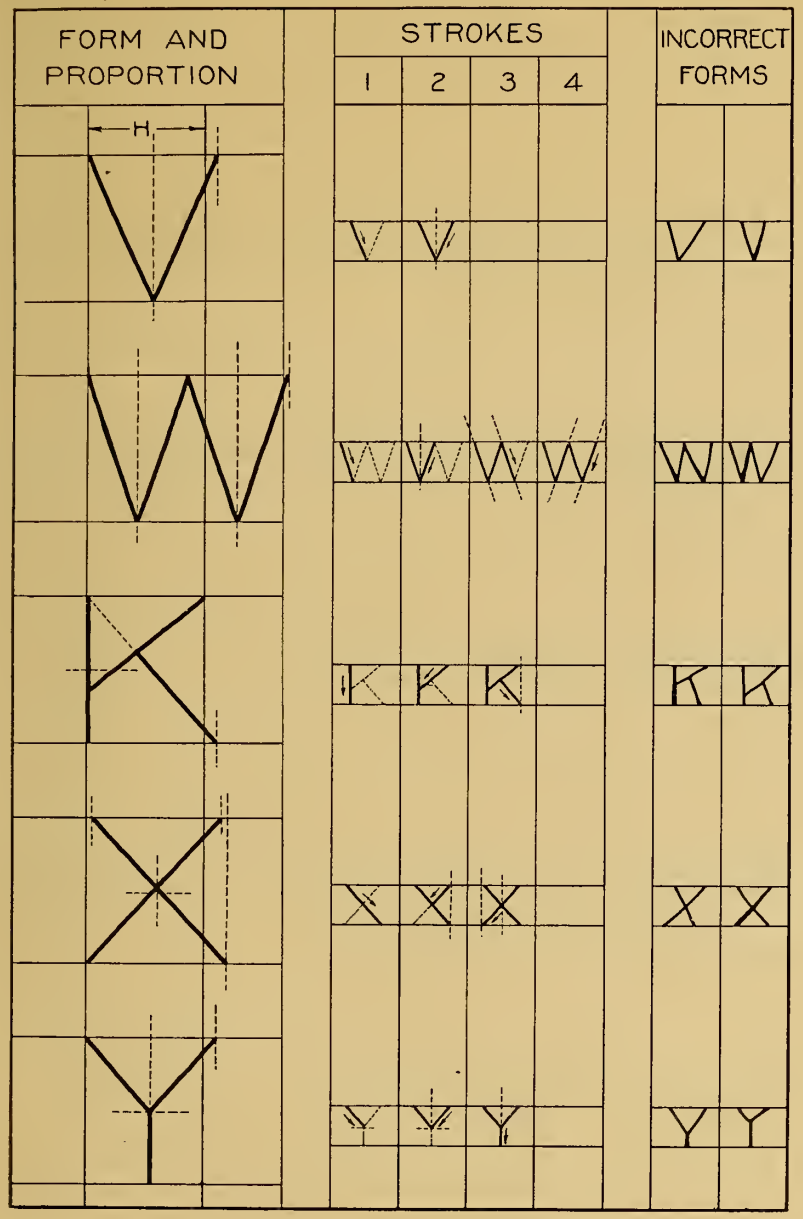
The length of the lower horizontal stroke is equal to the width of the H. The upper horizontal stroke is slightly shorter. Intermediate horizontal stroke as in the H.

The lower horizontal stroke is equal in length to the width of the H. The upper horizontal stroke is a little shorter. The right ends of the horizontal strokes are in the same vertical line.

The same width as the H.

The width and height are equal. The inclined strokes meet at a point one-fifth of the height of the letter above the lower guide line.

The width and height are equal. The intermediate horizontal stroke is one-third the height of the letter above the lower guide line.



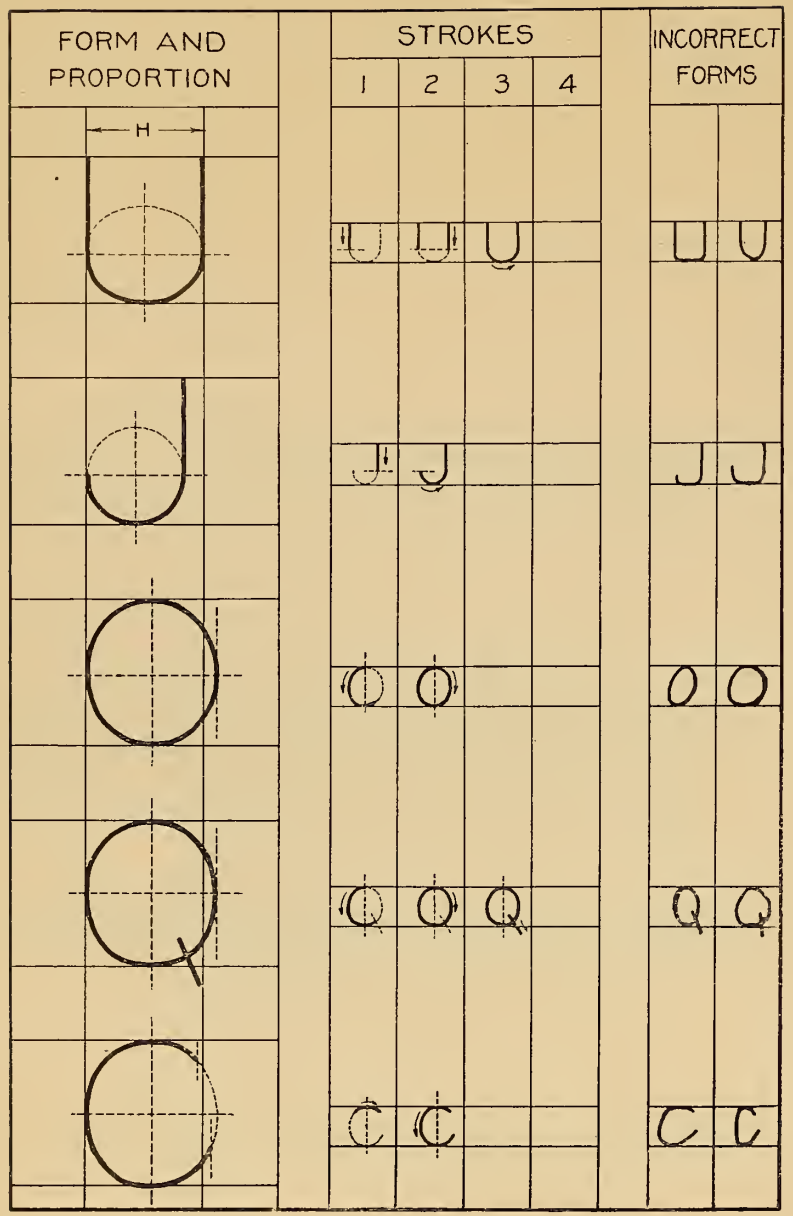
Wider than the H.

One and three-quarters times the width of the H. Strokes one and three are parallel and strokes two and four are parallel.

Width at the top of the letter is equal to the width of the H. The width at the bottom is slightly greater. The second stroke intersects the vertical stroke at a point one-third the height of the letter above the lower guide line. The third stroke if produced intersects the upper end of the vertical stroke.

Width and height are equal. The width on the upper guide line is slightly less than on the lower guide line. The inclined strokes intersect slightly above mid-height.

Slightly wider than the H. The inclined strokes intersect at mid-height.



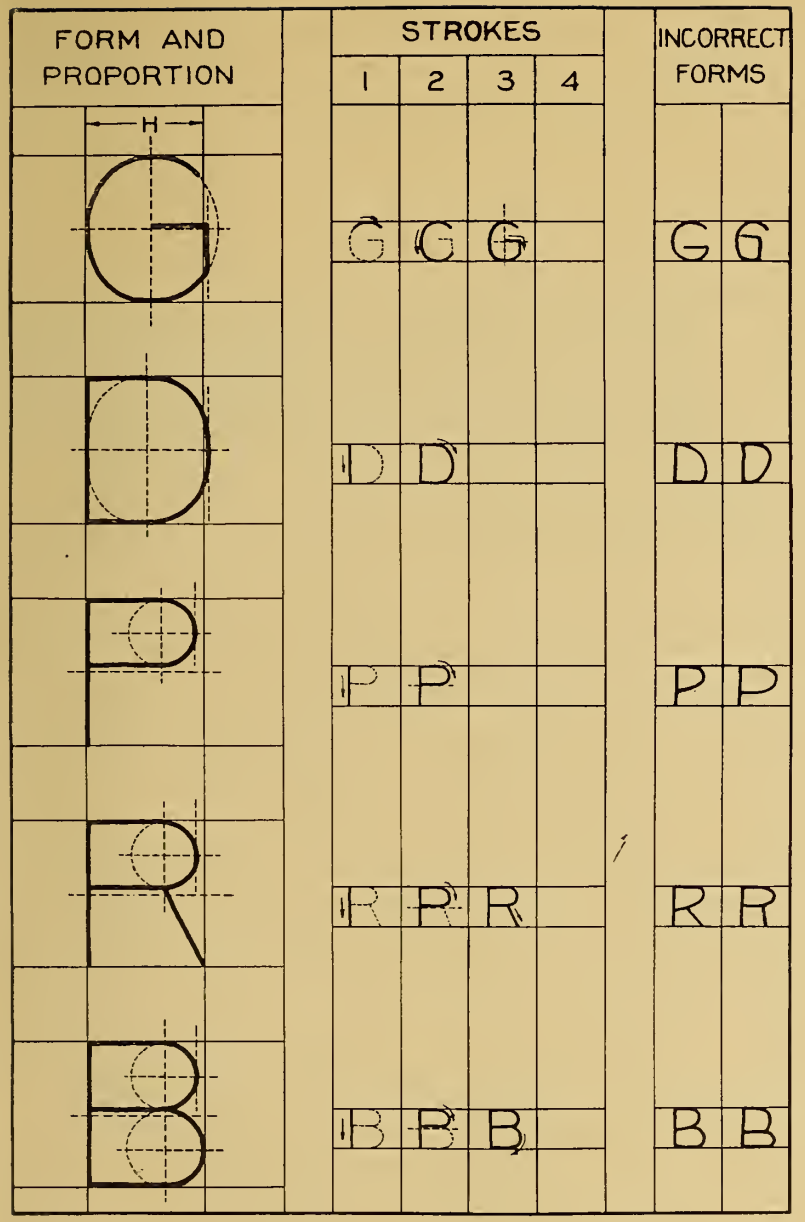
Width same as the H. The vertieal strokes are equal in length to two-thirds the height of the letter. The eurved stroke is a portion of an ellipse.

A narrow letter. The vertical stroke is equal in length to two-thirds the height of the letter. The eurved stroke is a semicircle.

Slightly wider than the H. An ellipse.

Same width as the O. The straight stroke extends a short distance below the lower guide line.

The oval is the same form as the O.



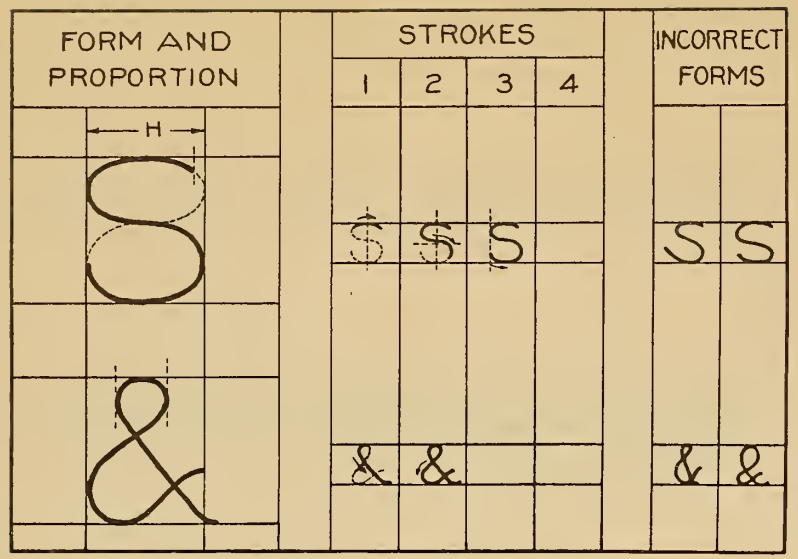
The same as the C, with the addition of the short horizontal and vertical lines. The horizontal line is slightly above the center.

Is slightly wider than the H. The length of the horizontal lines is equal to half the width of the letter. The curved part is a portion of an ellipse.

Slightly narrower than the H. The length of the horizontal portions of stroke two is a little more than two-thirds the width of the letter. The intermediate horizontal line is slightly above mid-height. The curved part is a semi-circle.

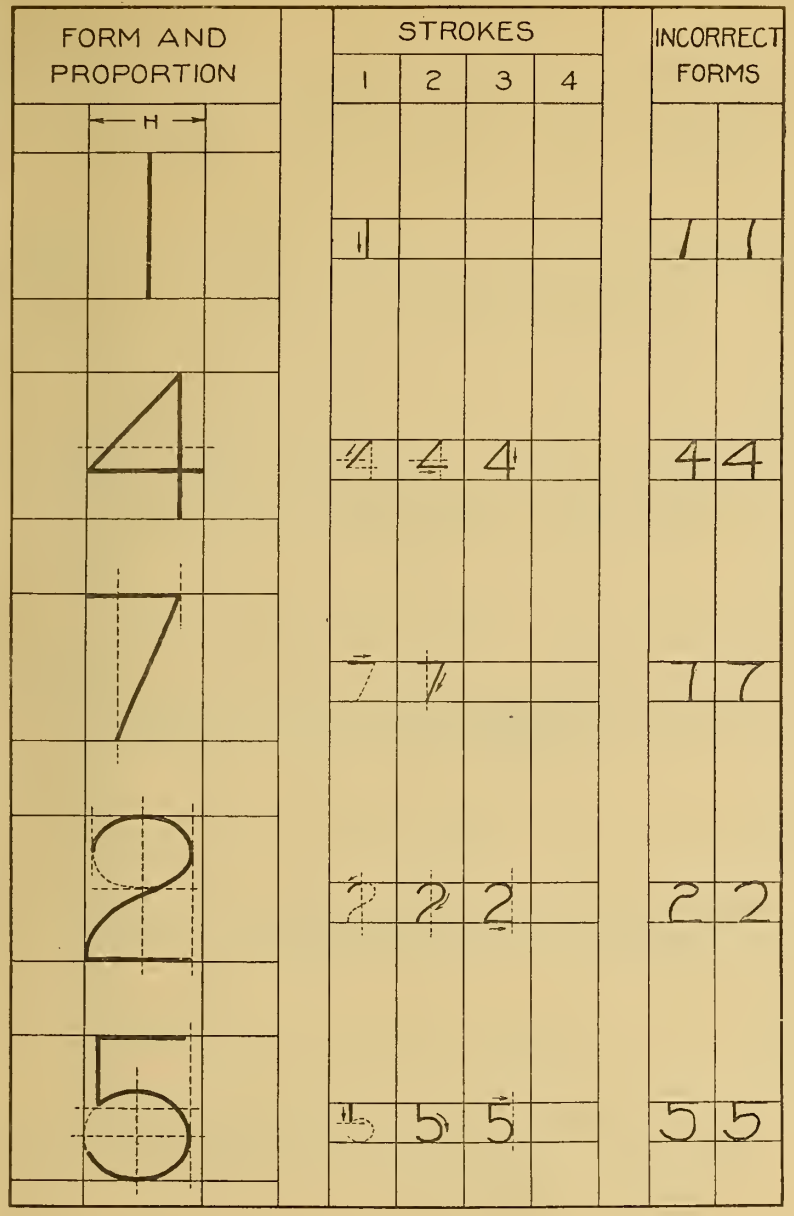
Same as the P, with the addition of the inclined stroke. The inclined stroke begins at the end of the curved portion of stroke two. The width on the lower guide line is a little greater than the upper portion of the letter.

The upper part of the latter is the same as the P. The lower portion is somewhat wider.



Same width as the H. The form is based on two ellipses, the height of the upper being less than that of the lower one. The ellipses are tangent at a point slightly above mid-height The first stroke ends a little to the left of the right hand vertical tangent to the ellipses. The beginning of the third stroke is directly under the extreme left point of the upper ellipse.

A little wider than the H.



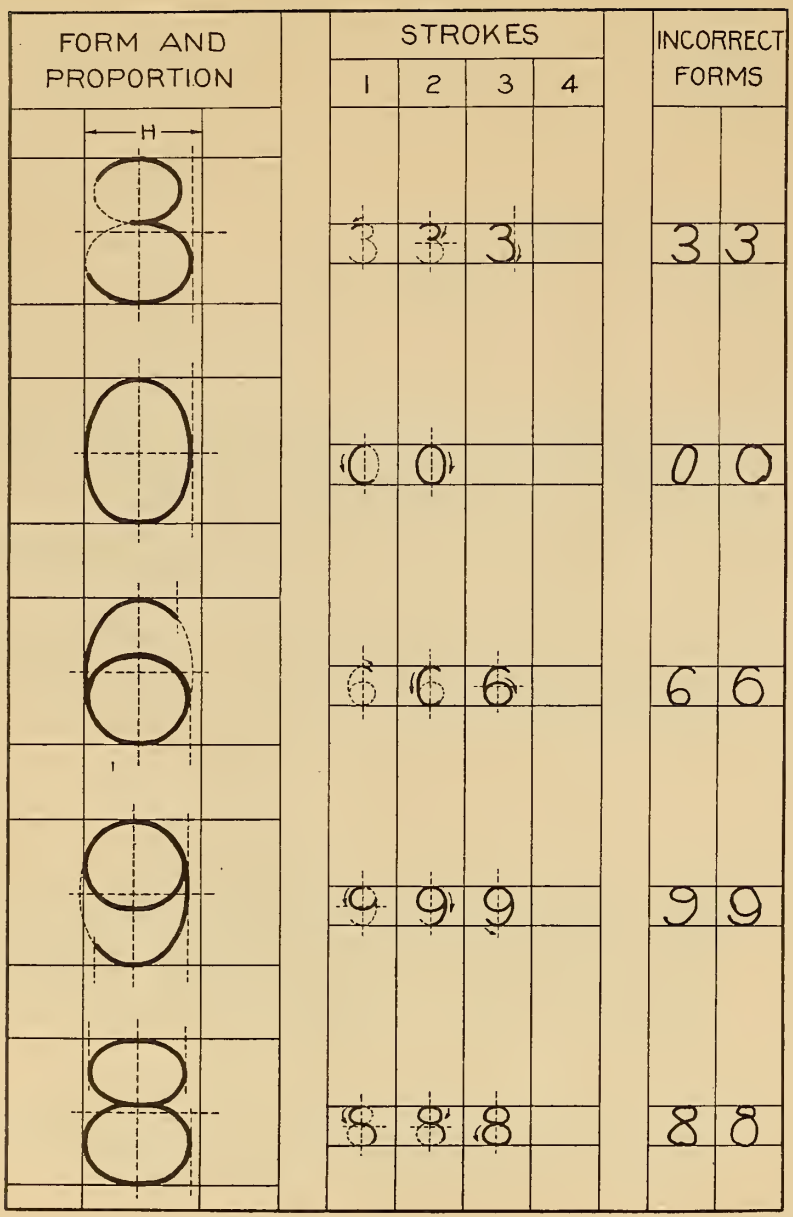
A single vertical stroke.

Same width as the H. The horizontal stroke is one-third the height of the numeral above the lower guide line.

A narrow numeral; the same width as the J. The second stroke ends one-third the width of the letter to the right of the beginning of the first stroke.

Slightly narrower than the H. The upper part is elliptical in form. The curve crosses the vertical axis of the ellipse produced a little below mid-height. The lower end of the curve is at right angles to the lower guide line. The upper width of the numeral is less than the lower, the contraction being on the left side. The horizontal stroke ends directly under the extreme right point of the curve.

Narrower than the H. The length of the first stroke is one-half the height of the numeral. The second stroke is almost a complete ellipse. The third stroke ends at a point slightly to the left of the extreme right point of the ellipse.



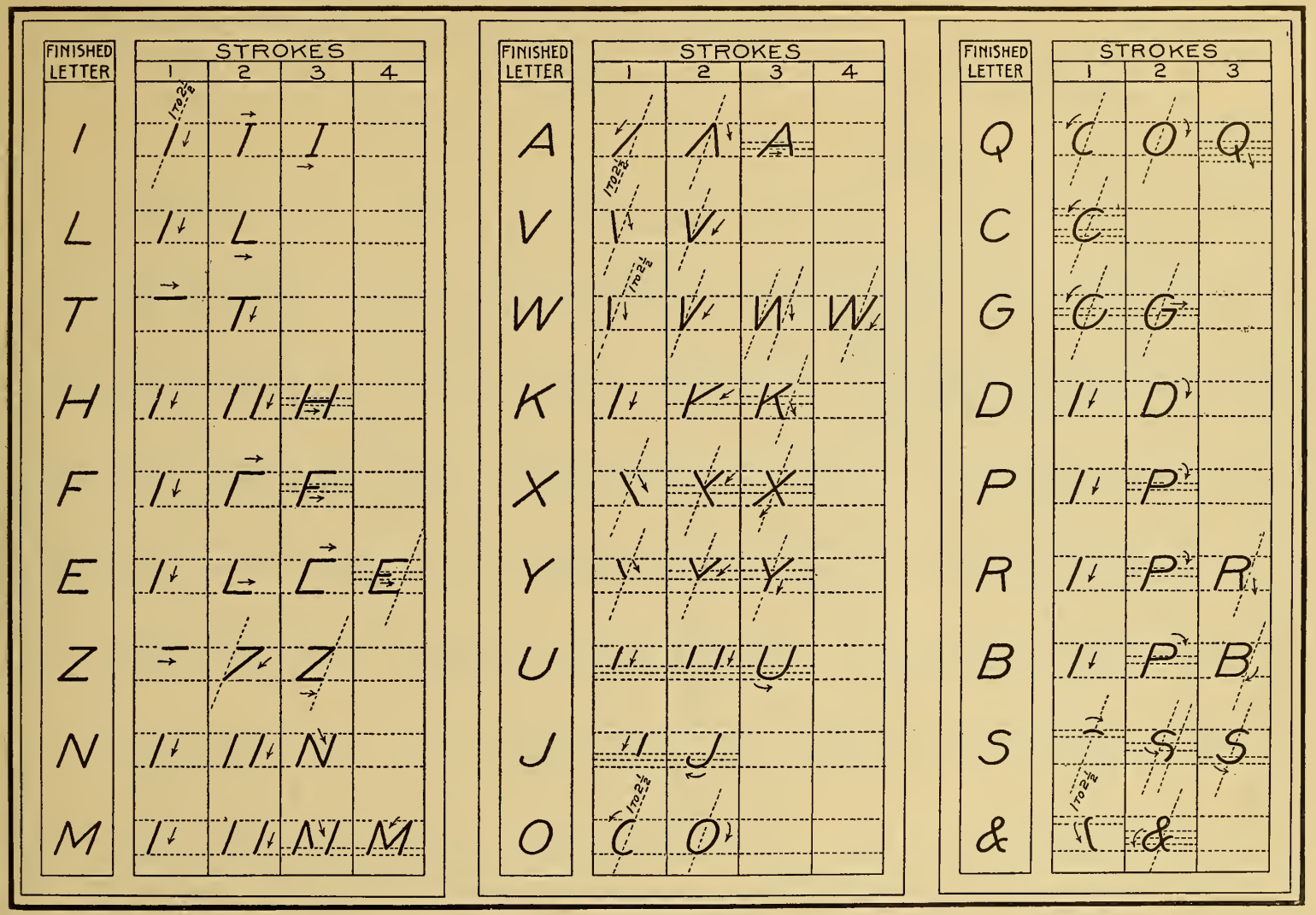
Narrower than the H. The form is based on two ellipses; the upper one smaller than the lower. The end of stroke two is slightly above the center.

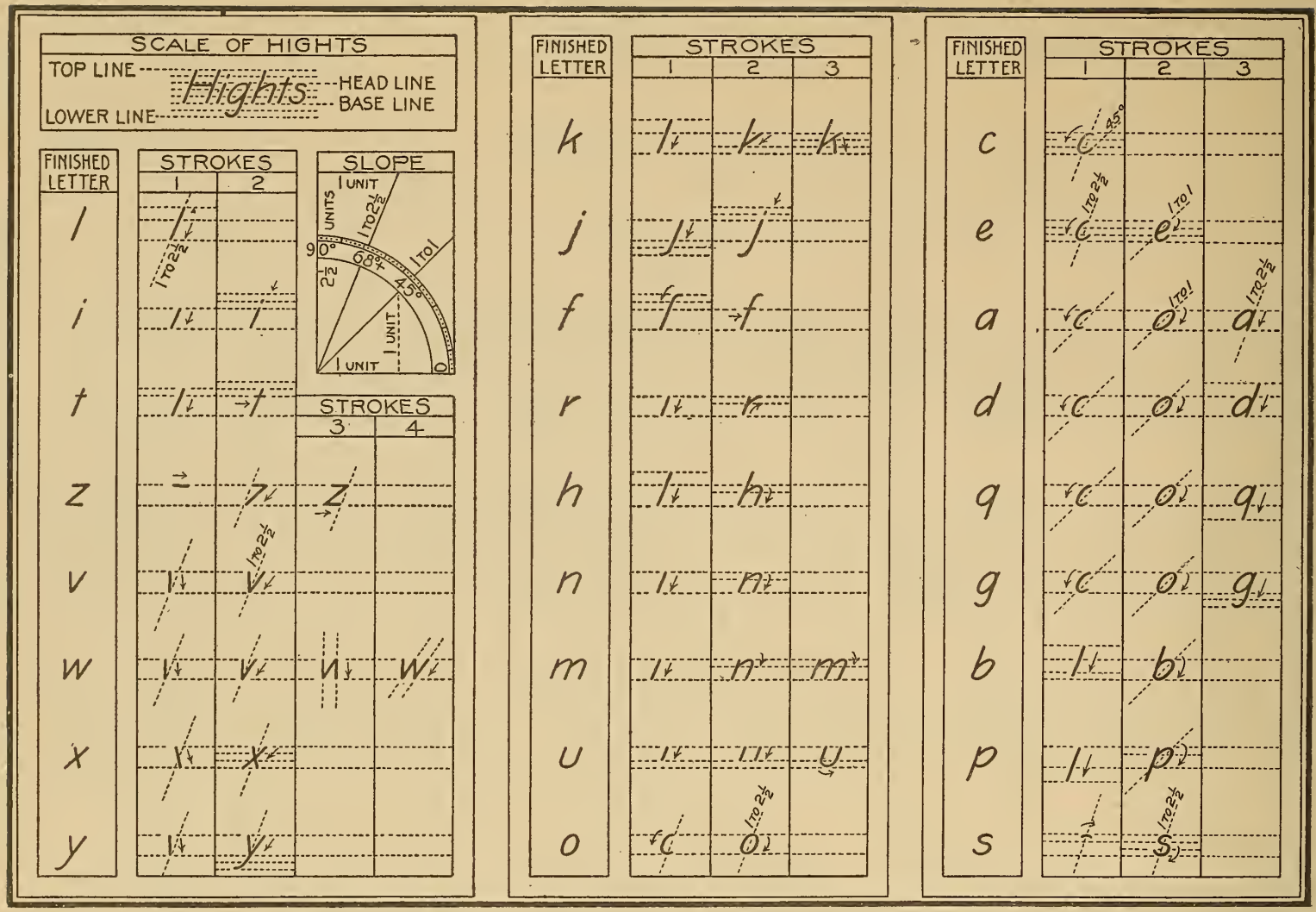
Narrower than the H. An ellipse. Notice that the zero is decidedly narrower than the letter O.

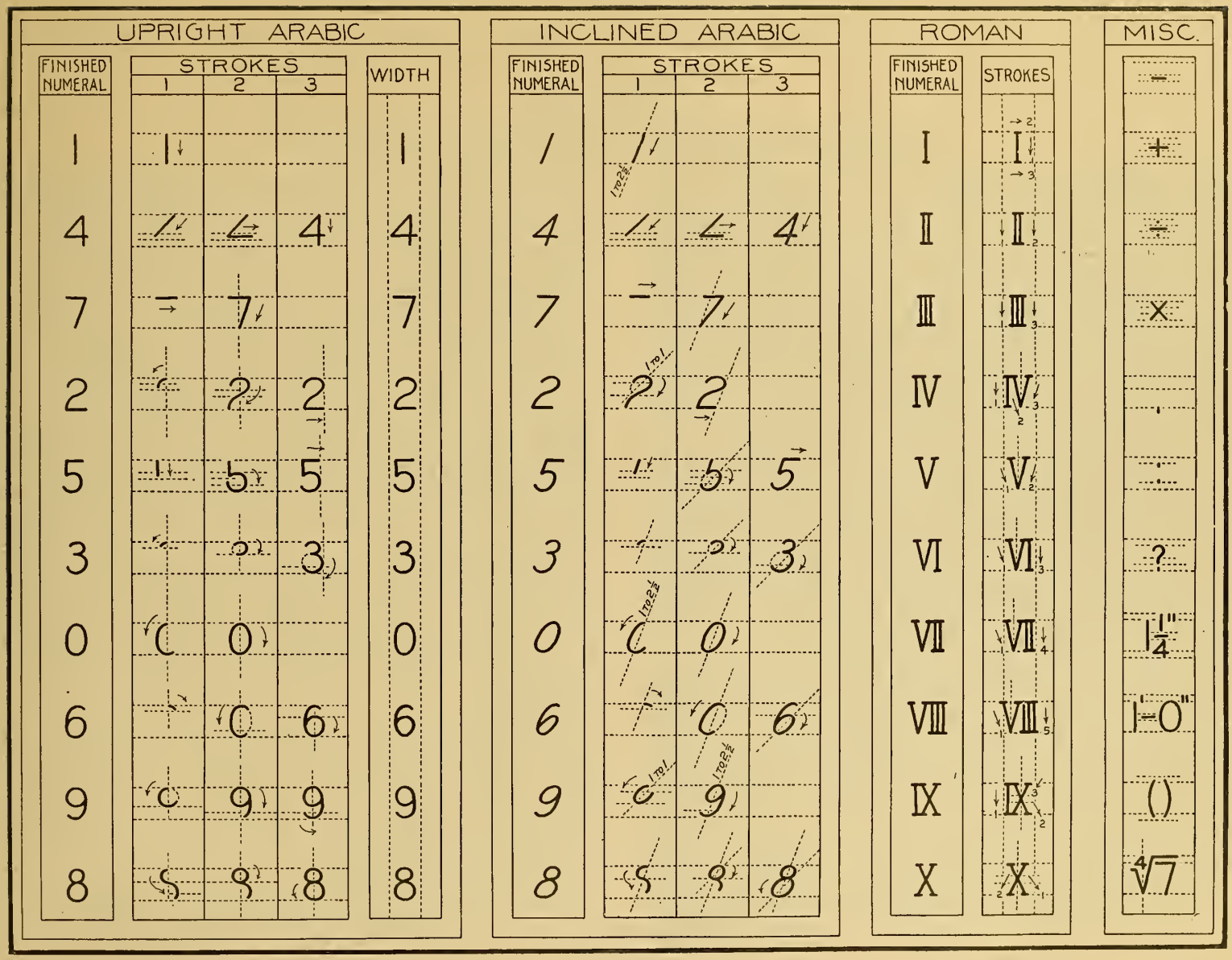
Narrower than the H. The form is based on an ellipse like the zero. The third stroke extends above mid-height.

Narrower than the H. The form is based on an ellipse. The first stroke extends below mid-height.

Narrower than the H. Two ellipses; the upper one smaller than the lower. The ellipses are tangent to each other at a point slightly above mid-height.


FINISHED LETTER
STROKES
1
2
3
4
I
L
T
H
F
E
Z
N
M
A
V
W
K
X
Y
U
J
O
Q
C
G
D
P
R
B
S
&


SCALE OF HIGHTS
TOP LINE
lights
HEAD LINE
BASE LINE
LOWER LINE
FINISHED LETTER
STROKES
1
2
3
4
SLOPE
1 UNIT
UNITS
1 TO 2½
1 TO 1
90°
68½°
45°
2½
0
FINISHED LETTER
STROKES
1
2
3
FINISHED LETTER
STROKES
1
2
3
45°


UPRIGHT ARABIC
FINISHED NUMERAL
STROKES
1
2
3
WIDTH
INCLINED ARABIC
ROMAN
STROKES
MISC.

CHAPTER 3

WORKING DRAWINGS, INSTRUMENTS AND CONVENTIONS

58. Instruments. The thing of prime importance to the student in beginning drawing is a good set of instruments. He had better have a fewer number and those of standard quality, than a variety of poorly constructed, cheap instruments. Beginners often think that a cheap set will do to learn with and a good set can be secured afterward. But it must be emphasized that while the student is learning is the time when he forms his drafting habits and sets his standard of excellence. He is inexperienced in handling the drafting instruments and hence, to obtain the best results, the best instruments are none too good. With a good set of instruments he is able to reach a degree of excellence consistent with his ability; he has a fair chance to make good, while with a poor set he is handicapped from the start, and can never obtain the results he might have obtained with a better set. It is difficult to define a "good" set of instruments so that the beginner will recognize them, for the better grades are extensively imitated, and he should be guided in his selection either by some more experienced draftsman, or the trade mark and the price set by some reliable dealer.

A good set differs from a poor one mainly in, that they are made of better material, are tempered correctly so that when once sharpened will remain so for a reasonable length of time, and the workmanship is such that they retain their alignment and adjustment when handled with reasonable care. These things can only be known definitely after the set has been given a fair trial.

Next to a good set of instruments is this consideration: *they must be taken care of*,—for as with any other delicate mechanism, the best results can only be reached when care is taken in their adjustment and the working parts kept in prime condition. It is often difficult to impress upon the student the importance of having a ruling pen or needle point sharp, or a compass joint nicely adjusted, but after some experience he will surely agree that perfection can never be attained with imperfect or poorly adjusted instruments.

59. Speed, Accuracy, and Neatness. The requisites for a good draftsman are speed, accuracy and neatness. The good draftsman combines accuracy and speed by a judicious handling of the instruments and a studied method of procedure. He does things in the most economical order. He looks ahead as far as possible and groups like operations so as to avoid unnecessary handling and adjustment of instruments. As far as possible all circles of the same radius are drawn while the compass is in the hand; all possible measurements are laid off from the scale at one time, etc.

All straight edges, angles, scales, etc., should be carefully tested, joints of instruments kept in good order and their points sharp; then by careful handling, fine lines and points in their proper positions may be secured in the drawing. The time used in sharpening pencils and keeping the instruments in good order is well spent.

Errors multiply with the number of operations involved, so other things being equal, the most direct construction is the most accurate. The location of points by very oblique intersections should be avoided.

The student should always sacrifice time to accuracy; speed will obtain through practice.

To secure neatness, the instruments should be kept clean, and in good working condition, and blotting and erasing should be avoided. Orderly habits aid greatly in securing neatness of work.

PLATE 1

EXERCISES WITH TRIANGLES, T-SQUARE, SCALE AND PENCIL

60. Drawing Boards. The drawing board should be made of well seasoned, straight grained, soft wood; free from knots and cracks. The best boards are designed to prevent warping, various means being used to accomplish this end. Some are built up of small strips glued together; others have a series of saw cuts in the back running lengthwise of the grain to reduce the transverse strength and are made rigid by cleats of hard wood screwed through slots equal in width to the diameter of the screw. This arrangement allows the board to expand and contract, the screws sliding back and forth in the slots.

(*a*) *Tests.* To test the surface of the board place a standard straight edge upon it in various positions and with the board held up to the light notice whether the straight edge is in contact with the surface at all points. Test the working edge of the board similarly.

(*b*) *Care.* The surface and edges of the drawing board should be kept free from cuts, scratches, and bruises. *Paper should be cut on the back of the board.* The board should not be subjected to extremes of temperature and moisture.

61. The T-Square is used for drawing parallel horizontal lines, and for directing the motion of the triangles. It consists of a rule called the blade attached to one end of which is a cross-piece called the head, which directs the motion of the blade by being pressed against the edge of the board. Lines are always ruled along its upper edge. The head is sometimes made movable so as to draw parallel lines in any direction. The blades are made of various kinds of wood, and of steel, or rubber. The most common forms are made of wood with edges of ebony, or celluloid. The steel blade is the most accurate, but tends to soil the drawing and smear dry ink lines.

The requirements are that the under surface of the blade shall be plane, and the working edge of the head and blade straight. It is not necessary that the edge of the blade be at right angles to the head.

(*a*) *Tests.* The best method for testing the edges of a T-square is a comparison with a standard straight edge. The edges of the blade may be otherwise tested as follows: Draw a line along the edge of the blade through two points on the paper, and mark the position of the end of the blade. Now swing the square around to reverse the ends of the blade with respect to the ruled line, keeping the *same side up* and bring the *same edge* to the ruled line, with the end on the mark and rule a second line through the two points. If the two lines coincide the blade is straight. In using the square the head should be held firmly against the edge of the board with the left hand, the ruling being done with the right.

(*b*) *Care.* Great care should be taken to preserve the square from injury. The upper edge should always be used for ruling, and should be kept free from cuts and bruises, *It should never be used as a guide for the knife in cutting paper.* If a straight edge is necessary in trimming drawings use the lower edge.

62. Triangles are used for drawing perpendiculars and lines at various angles, and for ruling parallel lines. They are made of wood, rubber or amber. The rubber and amber are the more accurate and the amber has the double advantage over the rubber that it does not attract dirt and soil the drawing, while it permits the lines to be seen through it. The forms most commonly used are the 45° and 60° triangles. With these any multiple of 15° can be constructed. Other forms are used for special purposes.

(*a*) *Tests.* The edges of a triangle should be straight and its angles true. The edges are best tested with a straight edge,—otherwise by reversion as explained for the T-square. The right angle may be tested as follows: Place the triangle in position D as shown in Fig. 70, and draw the line AB. If when the triangle is turned over into position C, the edge coincides with the line AB the angle is 90°.

When the right angles have been found true, the 45° angles are true if equal, and the 30° and 60° are true if one is double

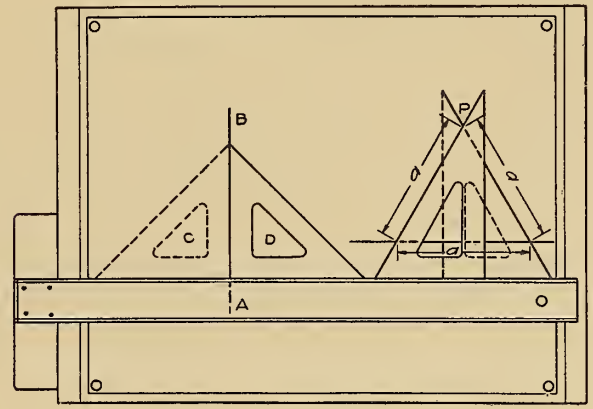


FIG 70

the other. These points may be tested by constructing the angles on paper thus: For the 45° angle draw a 45° line with one of the angles and bringing the other into the same position see if the edge coincides with the line. For the 30°, 60° triangle place the short leg against the T-square and draw two 60° lines through a point by reversing the triangle so that the lines make angles on opposite sides of the vertical. Fig. 70. Now draw a horizontal line cutting the two lines. If the triangle formed is equilateral, which may be ascertained with the dividers, the 60° angle, and also the 30°, is true.

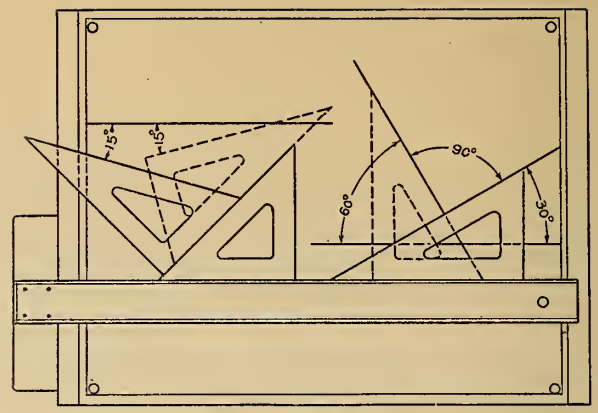


FIG. 71

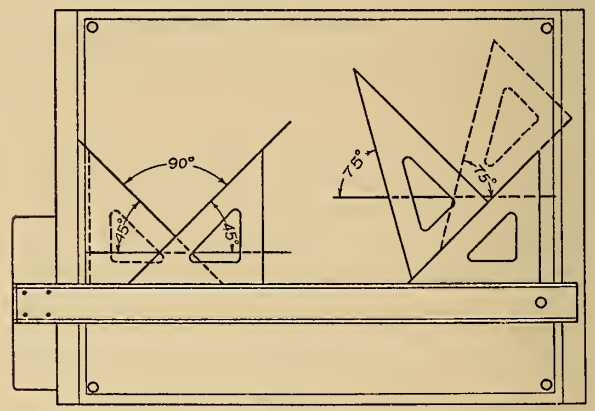


FIG. 72

(*b*) TRIANGLE AND T-SQUARE COMBINATIONS. *To draw lines making* 15°, 30°, 45°, 60°, *and* 75°, *with the horizontal.* Figs. 71 and 72.

In drawing a line through a given point in a line the T-square should be moved away from the line so that the edge of the triangle passes through the point. This principle holds in any combination. The straight edge which guides the motion of the ruling edge should not pass through the point through which the line is to be drawn.

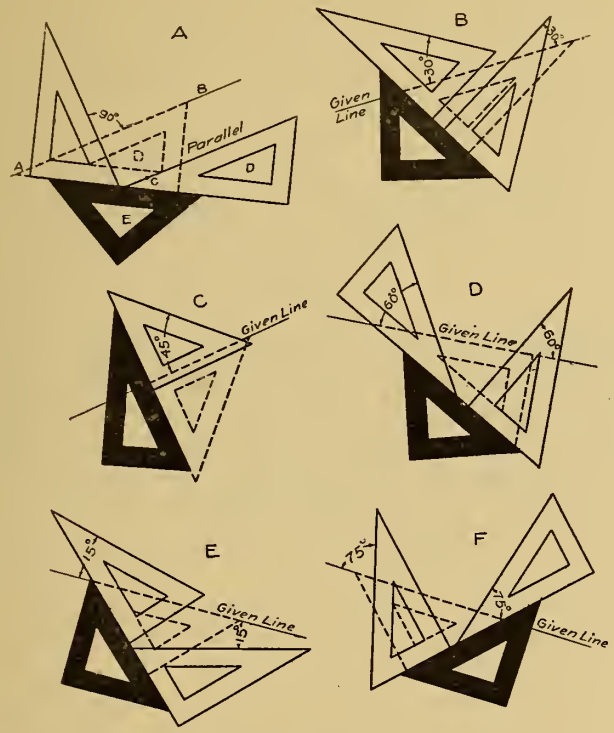


FIG. 73

(*c*) TRIANGLE COMBINATIONS. *Lines parallel or perpendicular to an oblique line, or making with it angles of* 15°, 30°, 45° 60°, *and* 75°.

For example, to draw a line parallel to AB through C. Fig. 73 A. Place triangle D so that one edge coincides with AB and fit triangle E against it. With E held firmly in place by the left hand slide D along until the edge passes through C.

In Fig. 73 the black triangle represents the fixed triangle and the dotted one is the movable one set upon the line. The full line shows the position in which the movable triangle guides the pencil, or the position of the triangle substituted for it.

63. Scales are used for making measurements and laying off distances. They are made of paper, ivory, boxwood, rubber, and steel, and are divided into all convenient units. The usual forms are the flat, with beveled edges, and the triangular.

The scale should be perfectly straight, the edges should be thin, sharp and free from nicks, and the graduations very fine clear-cut lines. The scale is usually a little over 12″ long, and is graduated for a distance of 12″.

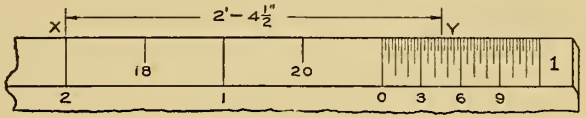


FIG. 74

(*a*) *The architect's scale* is divided on one face into inches, halves, quarters, eighths and sixteenths of an inch. The other five faces of the triangular scale have two scales each, one being one-half the other. To illustrate the reading of these scales, consider the one designated by a figure 1 at the end, which indicates that the scale reads 1 foot for each inch of the scale. The inch to the right of the 0 at the right end is divided into 48 equal parts so that each of the smaller divisions represents ¼″, and the spaces marked 3, 6, 9 represent 3″ each. To the left of the 0 the readings 1, 2, etc., are inches, and of course represent feet. Now to measure off for example a distance of 2 ft. 4½ ins. to the right of a point, Fig. 74, place the 2 opposite the point X and read to the right past the 0, 4½ ins. to the point Y.

In case you wish to read to the left place the $4\frac{1}{2}$ in. mark to the point and read to the left through 0 to the 2.

The scale should never be used as a straight edge in ruling lines.

64. Pencils. The lead of the drawing pencils should be of fine, even grain and of a hardness suited to the paper upon which the drawing is to be made. It should give a fine, firm, clean-cut line without pressure enough applied to crease the paper, so that in case it is necessary to erase no marks are left to disfigure the drawing. These properties may best be determined by trial. For the Duplex paper a 4H to 6H will be found suitable for the mechanical line work, and for the freehand work—letters and figures, a 2H to 4H is satisfactory.

65. Sharpening the Pencil and Compass Leads. The pencil point is one of the things most neglected by beginners and yet it is one of the most important of all the drawing instruments, requiring frequent and patient attention to secure good results. A dull or improperly sharpened pencil is not only inaccurate, but produces a mussy drawing, a thing which is almost certain to give an unfavorable impression of the student's ability as a draftsman.

(*a*) *The Ruling Point.* For ruling lines the wood should be cut away until about $\frac{3}{8}''$ to $\frac{1}{2}''$ of lead is exposed and this should then be ground to a chisel shaped point by rubbing opposite sides on a fine file or sand paper pad, holding the pencil at an angle of a few degrees to the plane of the pointer. Having produced a thin edge, round the corners slightly by rotating the pencil about its axis slowly while the former grinding motion is continued. Fig. 75. Compass leads should be sharpened in the same manner. The chisel point is particularly effective where a large number of long lines must be drawn.

(*b*) *The Measuring Point.* For laying off distances the point should be conical and very sharp. It is a good plan to sharpen one end of the pencil for ruling and the other for measuring. For freehand work the point should be conical but somewhat more blunt than the measuring point.

(*c*) *Manipulation.* The pencil should always be pressed very lightly upon the paper. In ruling along a straight edge care must be taken to hold the pencil constantly at the same inclination to the paper; i. e., move it parallel to itself. This is necessary in order that the line drawn be straight and parallel to the ruling edge. The rule should be flat upon the paper. Points should not be obliterated with pencil lines. If several lines are to be drawn through a point it is better to stop them a short distance from the point, so as to leave it clearly defined. A small circle should be drawn around points to indicate their position instead of making the points heavy.

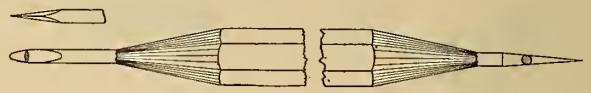


Fig. 75

66. Dividers are very similar to compasses in general appearance, the difference being that they usually have no lower joints, and that they have two very sharp points of steel. When closed they have the appearance of a single conical point. They are used either for laying off distances from the scale, or for transferring lengths from one part of a drawing to another. They may also be used to divide a line either straight or curved into any number of equal parts.

(*a*) *Manipulation.* A line is divided into a small number of equal parts by trial. First the required fractional length is estimated and then stepped off on the line. If it is not correct the first time an adjustment is made according to the size of the error. In stepping off distances on a line the dividers should be held by the handle between the thumb and forefinger, and swung alternately on one side of the line and the other. The plane of the legs should be perpendicular to the paper.

Do not make large holes in the paper.

67. Paper. The requisites of a drawing paper depend upon the character of the drawing to be made, and we need only con-

sider the qualities essential to a paper suitable for ordinary shop drawings.

The paper should be strong, and must stand erasure without spoiling the surface. As the drawings are to be traced the inking qualities need not be considered. Whatman's hot pressed is very satisfactory for precise line drawings. It has a smooth surface and stands erasure very well, but on account of being expensive is not much used in commercial drafting offices. *Detail* paper comes in rolls and is much cheaper and of inferior quality, but quite extensively used in office practice where working drawings are to be made and traced. It is of buff color, has a smooth surface and does not stand erasing very well. An excellent paper for fine pencil drawings is the Duplex. There are many styles and makes of paper on the market each having its particular advantages and disadvantages, for a description of which see dealers' catalogue.

68. Starting the Work. The first thing in order is to fasten the paper on the board. This is best accomplished by inserting a tack in the upper left hand corner, squaring it on the board with the T-square against the lower edge and then stretching it diagonally across to the other corner and inserting a second tack; now stretch it diagonally the other way and fasten as before. This method of procedure will insure the paper being stretched smooth and flat.

It will be found awkward to use the T-square near the lower edge of the board, and hence when the paper is smaller than the board it should be placed well above the lower edge.

69. Size of Plates. The finished plates are 11″ x 15″; the rectangular area enclosed by the border line is 10″ x 14″, thus providing a $\frac{1}{2}$″ space between the border line and the edges of the plate. The border line when drawn in pencil is a good, sharp, clean-cut line. In fastening the paper to the drawing-board—if the sheet is previously cut to about 11″ x 15″—the thumb tacks should pierce the paper $\frac{1}{4}$″ from each of the two edges. Upon removal from the board, the thumb tack holes should be closed by pressing back into place the paper disturbed by the tacks. If the sheet is larger than 11″ x 15″, the tack holes should not show in the finished plate.

70. To lay out the Border Lines. Lay out the 10″ x 14″ border line as follows: Working from the upper left hand corner of the sheet measure down $\frac{1}{2}$″; from the same corner measure $\frac{1}{2}$″ to the right. Draw a horizontal line through the first point and a vertical line through the second, thus locating two sides of the 10″ x 14″ rectangle. From the upper left hand corner of the border line lay off 14″ to the right and 10″ down, and through the points thus located draw the remaining sides of the rectangle.

PLATE 1

Make a complete pencil drawing of the figures as shown on page 47.

71. Figure 1. Page 47. Draw a horizontal center line for the sheet and on this center line measure 4″ to the right from the left border line. This will locate the center of Fig. 1. Through this point, using the triangle against the T-square, and the wedge-shaped lead of the pencil, draw EF perpendicular to the horizontal line. With the 45° triangle against the T-square draw AB. All lines should be drawn very light, no attempt being made to draw them of definite length. They may be gone over afterward, made more distinct and of the proper lengths. With the scale and the sharp conical point of the pencil lay off 2″ on each side of the center on AB. Through these points draw CE and FD perpendicular to AB. These lines will also be at 45° to the horizontal. Through the points where CE and FD strike the horizontal and vertical lines, draw ED and CF at 45° to the horizontal and parallel to AB.

On all four sides of the square thus formed lay off $\frac{1}{2}$″ spaces with the scale and sharp conical point of the pencil. In the triangles formed by the diagonals of the square and its sides draw alternate full and dotted lines as shown. Refer to Fig. 83 for methods of joining lines. All lines should be full and very light at first. Those that are to be dotted will be made so when the lines are gone over. *Omit all letters and dimensions from the finished plate.*

72. Figure 2. Locate the center of Fig. 2 as shown. Draw LM at 30° and ON at 60° to the horizontal. Draw PQ at 75° to the horizontal and on it mark points 2″ on each side on the center of the figure. Through these points draw LN and OM, perpendicular PQ, or what is the same thing at 15° to the horizontal. Through the points where these lines strike the 30° and 60° lines draw lines parallel to PQ (at 75° to the horizontal.) Lay off $\frac{1}{2}$″ spaces on all four sides of the square thus formed. In the triangles formed by the sides of the square and its diagonals, draw alternate full and dotted lines, as shown.

Draw the filing circle in the lower left hand corner of the sheet and letter therein the appropriate plate number, and filing number, using the dimensions as given in Fig. 75 A. Omit the sheet number. Add the initials below the filing circle, keeping the lines of figures and letters symmetrical with reference to an imaginary vertical line through the center.

73. Title. Letter the word "Exercises" in the lower right hand corner of the sheet, $\frac{1}{8}$″ above the border, and $\frac{1}{2}$″ from the right border line. The letters should be $\frac{1}{8}$″ in height.

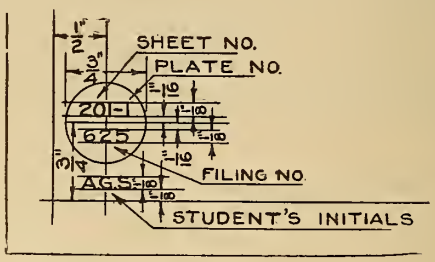


Fig. 75 A

Refer constantly to pages 29-36 when making the letters and numerals in the above.

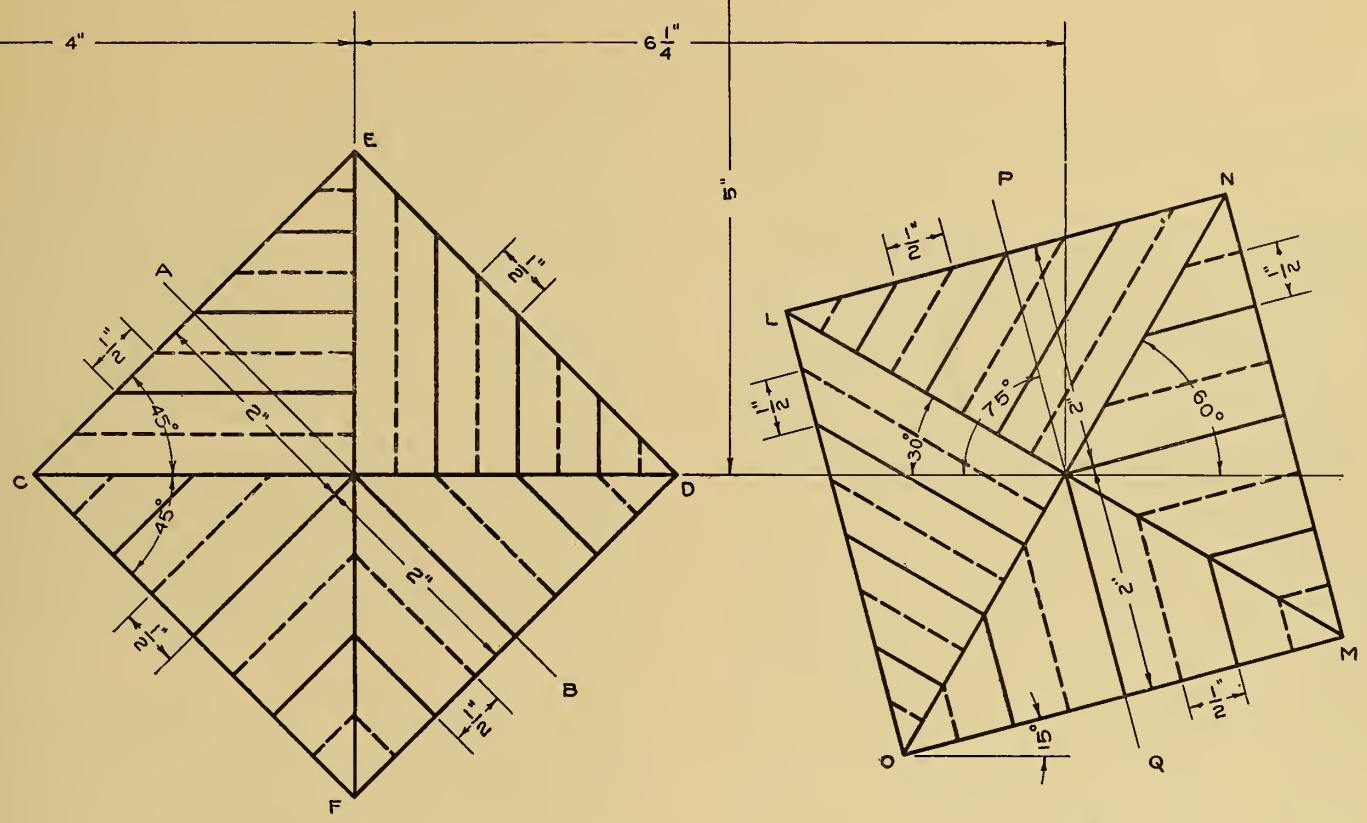


FIG. 1

FIG. 2

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UNIVERSITY OF WISCONSIN
DEPARTMENT OF DRAWING
COURSE 1

PLATE 2

EXERCISES WITH TRIANGLES, T-SQUARE AND RULING PEN

74. Ruling Pen. This is most used of all the instruments and should therefore claim considerable attention in its selection, manipulation and care. It is used for ruling lines in ink.

(*a*) *Construction.* It consists of two blades of steel connected by a screw for regulating the distance between the points, and these surmounted by a handle of wood, ivory, bone, or aluminum. One of the blades is usually provided with a joint or other device by means of which the blades may be spread apart for cleaning. The qualities that a ruling pen should possess are as follows: The steel should be of such quality as to retain a smooth sharp edge; the blades should be of the same length, and the inner one sufficiently stiff to resist a light pressure against the ruler; the points should be of the same width equally rounded and directly opposite each other.

(*b*) *Manipulation.* In using the pen it should be held in a plane perpendicular to the surface of the paper, the handle inclined a little to the right and the blades in a plane parallel to the ruling edge. It is held between the thumb and first and second fingers, the knuckles bent so that it may be held at right angles to the length of the hand, and with the points of the pen pressing lightly upon the paper. With the pen in this position draw it rather slowly from left to right. The motion should be one of the shoulder and elbow without bending the wrist. *Keep the forearm always perpendicular to the line being drawn, at whatever angle to the horizontal.* Endeavor to get into the easiest position for inking a line, even though it becomes necessary to walk around the drawing. The best results are secured by standing while inking. Care should be taken that the points of the nibs do not approach the ruling edge too closely or the ink will be drawn under by capillary attraction. When the line is inked move the ruling edge away from it to avoid blotting. Do not press the side of the pen point too heavily against the ruling edge, as the nibs will be pushed together and the width of line will vary. A certain touch, familiar to good draftsmen, brings the pen lightly but firmly in contact with both the cloth and the ruling edge. Steady the hand by sliding it on the end of the little finger. The pen should be moved from left to right, and should be drawn, not pushed.

(c) *Blotting.* With care blotting may always be avoided. It may be caused by (1) ink flowing under the rule by capillary attraction, (2) moist ink on the outer surface of the blade in contact with the ruler drawing ink by capillary attraction from between the nibs and finally to the paper, (3) touching the edge of the rule with the point of the pen in lifting it from the paper, (4) by drawing a line over a moist portion of the paper or over one that has been roughened by erasing, (5) filling the pen too full so that the ink is not sustained by capillary attraction.

(*d*) *Filling the Pen.* The pen is filled by drawing the quill attached to the stopper of the ink bottle between the nibs. When filled the ink should not stand more than $\frac{1}{4}''$ to $\frac{3}{8}''$ from the end of the nibs to avoid blotting. When the ink does not flow freely from the pen it should be removed, the pen thoroughly cleaned and supplied with fresh ink.

(*e*) *Care.* Clean the pen while in use by inserting a piece of cloth between the blades and drawing it out through the nibs without moving the thumbscrew. Ink dries quickly so that the pen should not be laid aside for any length of time without cleaning. After using the pen it should be carefully cleaned by separating the nibs and wiping with a piece of chamois skin or

one of the pen wipers which come with prepared inks. If the ink is allowed to corrode it may ruin the surface of the nibs, thereby spoiling the pen.

(*f*) *Setting and Grinding the Pen.* The blades should be of precisely the same length, the points of the same width, rounded in two directions, and as sharp as they can be made without producing the sensation of cutting. They should not scratch the paper when drawing a line. This occurs if they are sharpened to a point instead of a rounded edge, or if the point is rough or notched. Any irregularities in the length of the points may be detected by holding the pen up to the light so as to see both points, and then closing them slowly.

In case of irregularities or the pen becoming dull from use it may be treated as follows: Close the nibs until they just touch each other and then, using a close-grained oil stone, hold the pen as though to draw a line and draw it back and forth, revolving it slowly in the plane of motion which is perpendicular to the plane of the stone. This will dull the nibs, but it will grind them into the desired rounded point. Grind until the nibs are of equal length. If the pen now be held up to the light with the nibs separated and the points directed to the eye so as to catch the angle of reflection of the light, a bright speck will be seen on the points. This must be reduced by rubbing the outside of the nibs on the oil stone, giving at the same time a slight rotary motion to the handle, which is held at an angle of 15° or 20° with the face of the stone; the point of the pen being examined from time to time, and the process continued until the point is as fine as can be used without cutting the paper.

All grinding should be done on the outside of the nibs. To remove the burr from the inside use a piece of leather or soft pine.

75. Erasure. Many students find trouble in erasing from the tracing cloth without marring the drawing. If proper care is taken ink may be erased so that the surface of the cloth is hardly affected. A shield of brass or celluloid should be used and the opening in it which best fits the line or spot to be erased selected. By holding it firmly with the fingers of the left hand and employing an ordinary pencil eraser in the right, the ink will readily yield. Finish by polishing with a smooth surface such as the thumb nail, a piece of ivory or soapstone.

76. Tracing Cloth is the medium most generally used for reproducing the original drawing in the form of prints. It is a firm transparent cloth covered with a sizing. The side on which the sizing is placed is very smooth and glassy, while the other side is less so.

The time worn question of which side of the cloth is to be used is best decided by considering the nature of the work to be done. The glazed side was primarily intended for use and hence was rolled in, but the cloth will curl when inked on this side. From the fact that there is more sizing on the glazed side, the ink, especially red ink, does not eat so deeply into the cloth and hence is more easily erased from this side. If work is to be done in pencil it must be done on the dull side in order that the pencil lines show. The dull side takes ink more readily, without so much danger of blotting, and the cloth does not curl. In general it is safe to say that where much erasing is to be done the bright side is preferable, but where penciling is to be done on the cloth the dull side must be used. Beyond these considerations the choice rests entirely with the draftsman.

If the surface of the cloth appears greasy so that it does not take the ink readily, it should be either washed with gasoline or benzine, or be rubbed with finely powdered chalk, taking care to remove all of the chalk before trying to ink again, as it will clog the pen. It may be washed with gasoline or benzine to remove pencil marks or smudge after the drawing is finished, without affecting the ink.

Tracing cloth is affected by the moisture of the air which causes it to stretch, and water will ruin it.

77. Blue Print Paper is made of several different grades of white paper covered with a coating sensitive to light. In printing, the inked side of the tracing should be placed next the glass in the frame or machine, and then the sensitive side of the paper

next the tracing. They are held tightly in this position by a board or cloth, and exposed to a bright light for a time, depending on the "speed" of the paper. That part of the coating protected from the light by the lines on the tracing is washed away when the print is placed in water while the exposed portions turn blue; hence the result is white lines on a blue ground. These prints may be mounted on a smooth flat surface and given a coat of shellac, thus forming very durable shop drawings.

PLATE 2

Make a complete tracing of Plate 1.

78. To Stretch the Tracing Cloth. Use the dull side of the tracing cloth. It is cut slightly larger than the drawing paper and the greater part of the extra area is to be left at the top and right hand sides. This extra area is used to try the pens on, before inking in the work. Remove the lower left hand tack from the drawing. Place the tracing cloth over the drawing so that it extends about $\frac{1}{8}''$ beyond the lower and left hand edges of the paper. Insert the tack into the hole that it previously occupied. Remove the tack from the upper right hand corner of the sheet. Stretch the tracing cloth diagonally, and insert the tack as before. Proceed in a similar manner with the other two corners. The tracing cloth should lay flat on the drawing paper. If tracing cloth is allowed to remain on the board some time its surface becomes uneven on account of changes in the atmosphere. If the cloth becomes uneven it should be restretched as described above. The tracing cloth should not be fastened over the drawing until the tracing is to be started.

79. Lines. Both the full and the dotted lines should be object line weight or $\frac{1}{64}''$ in width. It is good practice to ink the squares, rectangles and triangles until not only the lines are good, but the corners and intersections as well. Corners should be very definite. Be careful to stop each line at exactly the right point, for ragged corners and poor intersections indicate careless work.

Border Line. The border line should be a heavy black line $\frac{1}{32}''$ in width on the tracing.

80. Pencil Guide Lines. The student should rule guide lines for all lettering, using a 3H pencil. Guide lines ruled on the drawing paper will not answer when lettering on the tracing cloth. Ruling the guide lines on the surface to be lettered gives better results.

The tracing cloth should be carefully cleaned with a soft rubber in order to remove all pencil and other marks before blue printing. A hard eraser should not be used for cleaning purposes as it will remove the ink from the lines of the drawing.

81. To Cut the Tracing Cloth to the required size, after the drawing is completed, use a very sharp knife. The working edge of the T-square should not be used to guide the knife.

PLATE 3

EXERCISES WITH COMPASS AND BOW PENCIL

82. Compasses are used for drawing circles or arcs of circles. For very large circles the lengthening bar may be added, and when this does not suffice, a beam compass may be used. The bow compass is best for circles under $\frac{3}{4}''$ radius.

(*a*) *Construction.* They are best made of rolled German silver, and should combine lightness with rigidity. The vital part of the compass is the head which in the modern instruments consists of two discs forming the heads of the legs held in apposition in a fork by means of two pivot screws, which also serve to adjust the bearing. The top of the fork terminates in a handle. The thing next in importance is the socket joint of the removable pen and pencil parts.

(*b*) *Tests.* All joints in a compass and its parts should work in the same plane. To test the compass for this, place the parts in the socket and bend the legs out at the head, and then bring the points together by bending at the lower joints. If the points come exactly together the joints are true. This is also a test of the alignment of the shank in the socket.

(*c*) *Setting the Lead.* Before attempting to use the compass the lead should be sharpened as described in Art. 65 and set as follows: Place the pen in the compass and adjust the needle so that it projects slightly beyond the nibs of the pen; remove the pen, replace the pencil and adjust the lead so that it is slightly shorter than the needle point.

(*d*) *Manipulation.* In describing a circle the needle point and pen or pencil parts should be bent so that they are perpendicular to the paper. The needle point will then make only a small hole, and the nibs of the pen will bear equally upon the paper, which is a condition that must be fulfilled in order that the line may not be ragged.

Having set the compass approximately and adjusted it exactly with the hair-spring thumb screw, grasp the handle between the thumb and forefinger and with the needle point resting lightly on the center, and the compass leaning a little in the direction of motion, start with the lead or pen about under the wrist and swing in the circle without stopping. The motion should be in a clockwise direction. Let one passing of the lead or pen suffice. Do not go over the line again either backward or forward.

When using the lengthening bar, the length of which makes the instrument somewhat unwieldy, the pen or pencil part should be steadied by grasping it lightly between the thumb and forefinger of the free hand.

(*e*) *Care.* The compass should be carefully guarded against injury. Falling on the floor may spoil the alignment. The needle point should always be very sharp. When dull it may either be sharpened on a fine grained oil stone or replaced by a new one. It is a common fault with beginners to clamp the points and head joint too tight, with the idea that they will remain more securely in place. The joint should work easily. If clamped too tight it is difficult to set the points to the required distance as they will spring slightly when released. The screws should not be set down hard in clamping the points as this destroys the screw threads. The points will remain securely in place with careful handling if clamped lightly.

83. Bow Pen, Bow Pencil and Bow Dividers. The bow pen and pencil serve the same purposes as the compass, and the bow dividers take the place of the large dividers, in describing small circles, and laying off small distances, where the larger ones are too heavy and less accurate. They have the advantage that they retain their adjustment.

84. Titles. The relative importance of the various items of the title is shown by their arrangement and the character of the letters in which they are printed.

(*a*) *Balancing the Title.* A title of two or more lines should be arranged so that the middle point of each line is on the same vertical straight line. The title is then said to be balanced. To balance the title each line should first be lettered on a scrap of paper, taking care to make it accurate in height and to space the letters correctly. Each line should be complete in itself, but it need not have any definite relation to the other lines at this stage. Mark the middle point of each line and cut out strips of paper containing the lines. Fig 76A. Draw pencil guide lines on the sheet according to the layout given. Select the strip containing the longest line of the title and lay it above its space on the sheet with one end of the line one-half inch from the right border line. Fig. 76 B. Mark the middle point on the sheet and draw a vertical line through it. This will be the center line of the title. The printed lines may now be laid above the spaces with their middle points on the center line and lettered according to the spacing on the trial slip.

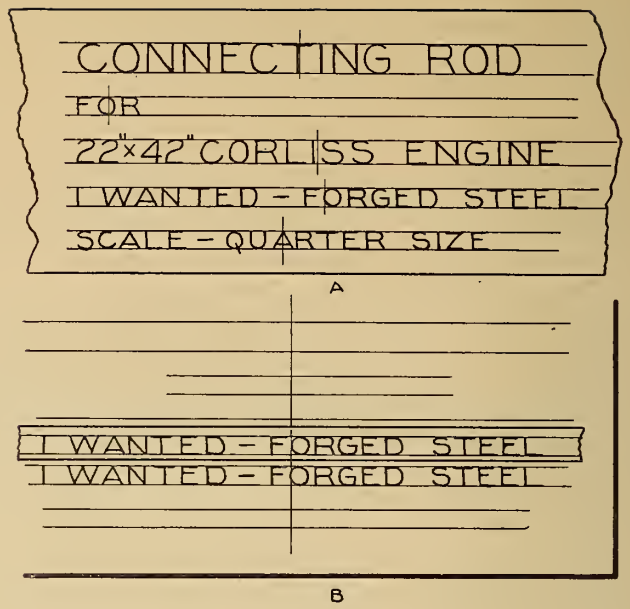

FIG. 76

PLATE 3

Make a complete pencil drawing of the figures on page 53 as shown.

85. Penciling. In making dashed lines with the compass the lead should be sharpened to a conical point in order that the end of the dashes may be made distinct. A vertical and a horizontal center line should be put through the center of the circles. They should extend about $\frac{1}{2}''$ beyond the largest circle. All dimensions, dimension lines, numerals and letters, except those in the title and filing corners of the plate, should be omitted.

86. Figure 1, Page 53. Locate the center of the figure as shown. With the scale and a very sharp pencil, mark off the given distance on the radius A. NOTE. Insert a piece of "4H lead" in the pencil leg of the compass and bow pencil. The leads sold with the instruments are too soft. Draw the smallest circle first, drawing the dashed circles as shown. Keep the leads sharp.

87. Figure 2, Page 53. Insert the lengthening bar in the compass, and with the center at B describe arcs as shown. Draw the filing circle in the lower left hand corner of the sheet, and letter therein the appropriate plate number, and filing number. Add the initials below the filing circle, keeping the lines of figures, and letters symmetrical with reference to an imaginary vertical line through the center.

88. Title. Lay out the guide lines for the title in the lower

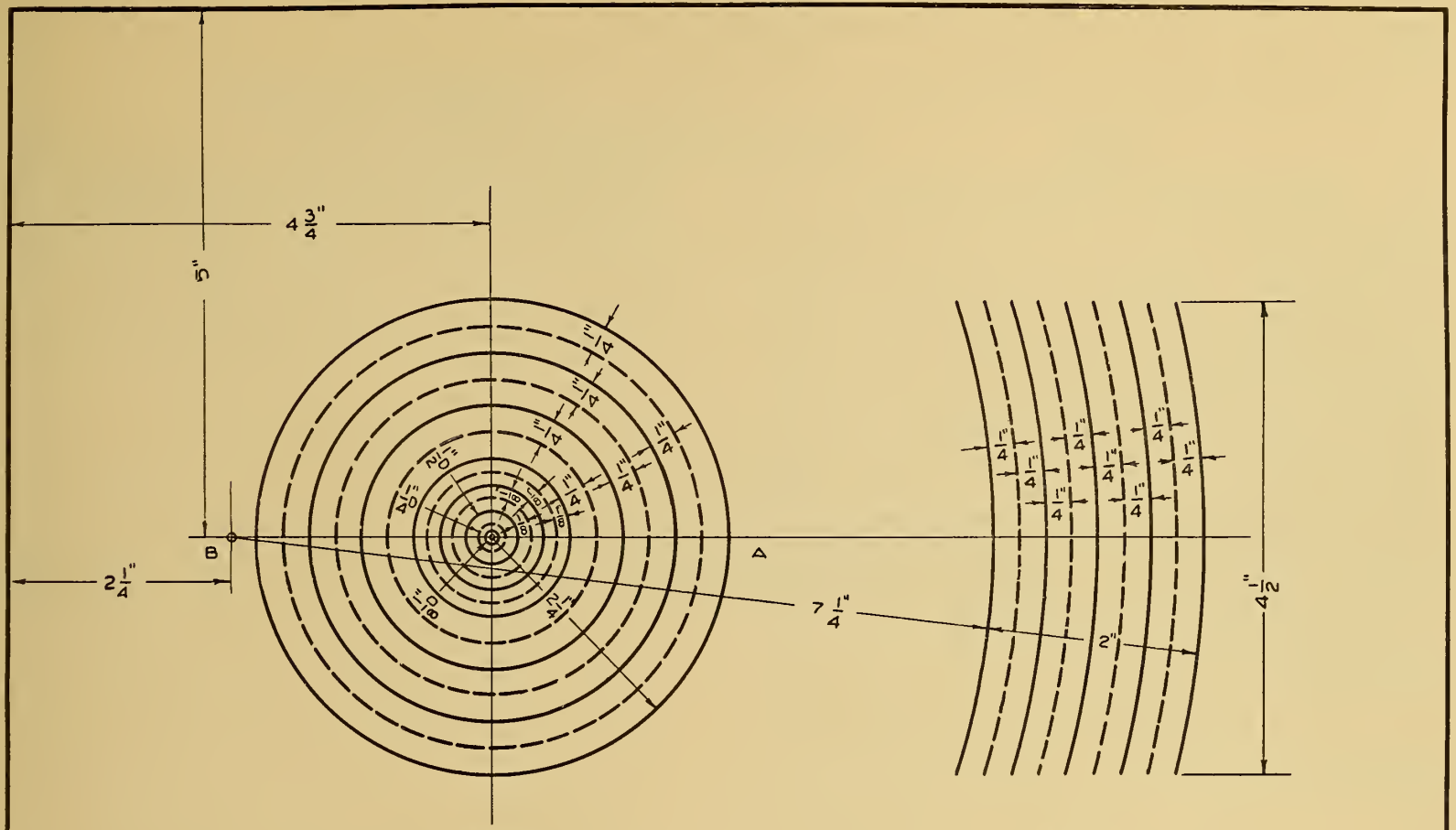

FIG. 1

FIG. 2

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DEPARTMENT OF DRAWING
COURSE 1

right hand corner of the sheet according to the lay out given in Fig. 77.

Letter the following material arranged as given:

EXERCISES
WITH
COMPASS, BOW PENCIL AND BOW PEN

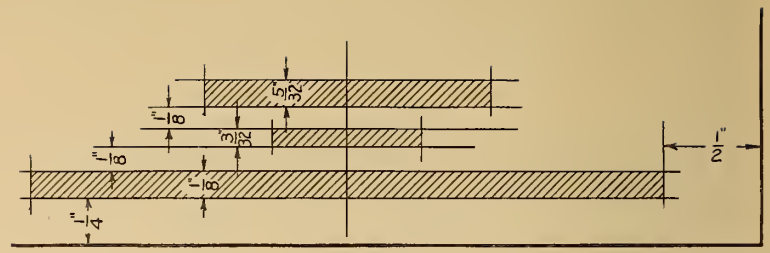


FIG. 77

PLATE 4

EXERCISES WITH THE COMPASS AND BOW PEN

89. Make a complete tracing of plate 3.

Practice with the compass and bow pen before inking the required plate.

PLATE 5

SHOP DRAWING IN PENCIL. PLANER CHUCK JAW
FREEHAND SKETCHING

90. Materials. The outfit for this course consists of a pencil, a pad of cross section paper and a soft eraser. When sketching from models a scale, inside and outside calipers and other special tools for taking measurements will also be needed. Sketches made from the dimensioned perspective drawings in these notes will not require the use of the measuring tools. A

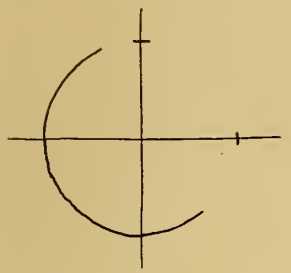


FIG. 78 A

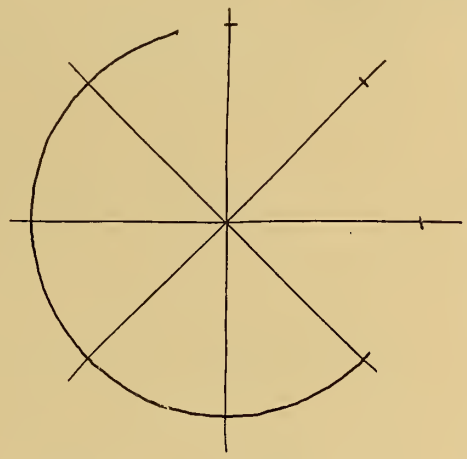


FIG. 78 B

3H pencil is recommended. Cross section paper divided into one-eighth inch squares and printed in faint blue lines should be used.

91. Straight Lines. The pencil should be sharpened to a conical point. Sharpen the pencil often. All lines should be made freehand, including the circles. The hand should rest on its side, the pencil being held nearly perpendicular to the line to be drawn. This position makes it possible to draw lines from one to two inches long. When longer lines are necessary they should be made in two or more strokes, each stroke beginning at the end of the previous one. Avoid drawing freehand lines by making short overlapping strokes. Each line should be drawn faintly at first. If a line is not properly placed or its direction is not correct it should be erased and redrawn. After all of the views have been completed the lines should be gone over, making them distinct. In going over the lines they should not be thickened.

92. Circles. To sketch a circle the horizontal and vertical axes are first drawn, as shown in Fig. 78A. Points on the circumference are located by estimating the length of the radius from the center of the circle. When the circle is small four points are sufficient. For larger circles additional lines should be drawn at 45° with the horizontal axis and points located on them in the same manner. Fig. 78B. The same method may be employed for arcs of circles. To sketch an ellipse the ends of the major and minor axes should be located.

93. To Complete Sketch. In making a freehand sketch proceed in the following manner. Each step should be completed before the next step is considered:

1. Determine the number and kind of views. The views that best represent the object should be selected.
2. Locate the group of views on the sheet and block out each view. See Art. 94.
3. Draw the center or datum lines.
4. Complete the views in light lines, proportioning the parts by eye. The divisions on the cross section paper should not be used as a scale.

5. Make all lines clear and firm.
6. Insert dimension and extension lines.
7. Draw arrowheads.
8. Put in the dimensions. The arrowheads and numerals should be as carefully executed as those on a mechanical drawing.
9. Section-lining.
10. Letter the title and add the data in the filing circle. On a sketch the height of the letters in each line of the title should be the same as for a mechanical drawing. It is not necessary, however, to balance each line on a vertical center line. An example of a title for a sketch is shown in Fig. 79.

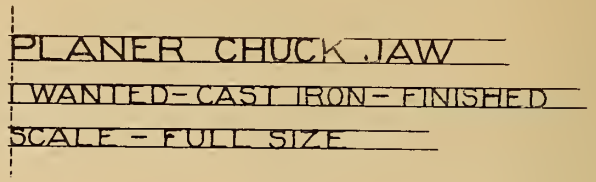


FIG. 79

WORKING DRAWINGS

94. Planning the Drawing. In deciding the scale of a drawing the draftsman must consider not only his convenience in drawing the views on the sheet, but also the use to which the drawing is to be put. It should not be of such a size as to be unwieldly to the mechanic nor small enough to be confusing.

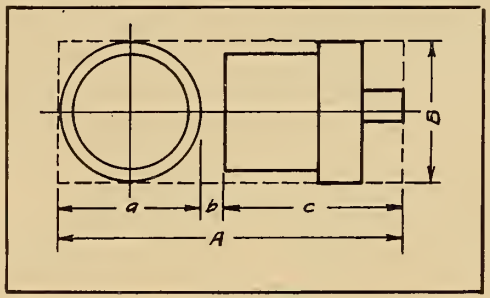


FIG. 80

(*a*) *Number, Kind and Arrangement of Views.* The number of views is determined by what the draftsman's judgment tells him makes the drawing thoroughly intelligible to the mechanic.

All necessary views and no more should be given. Select views that show the object in the most comprehensive manner. Sectional views often make the inside of an object clearer to the mechanic.

The views must always have a fixed relation to each other according to the rules of third angle projection.

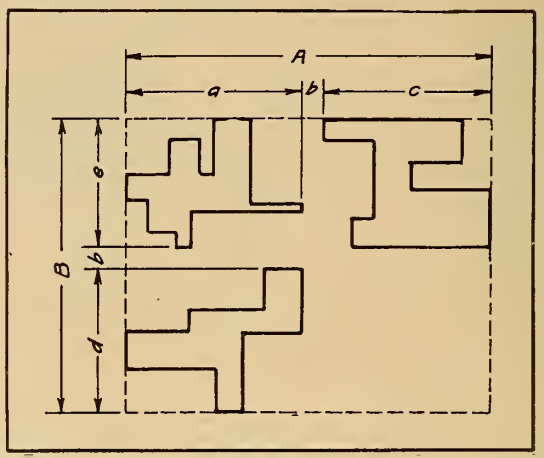


FIG. 81

(*b*) *Location of Views with Reference to Each Other.* The distance between views of an object should be as small as possible and still have each view stand out as a distinct view. For the problems of this course the distance between views should as a rule be not less than $\frac{3}{4}''$ nor more than $1''$.

(*c*) *The Enclosing Rectangle.* The rectangle in which the views are inscribed is known as the enclosing rectangle. The dimensions of the enclosing rectangle are determined for two views as follows: Fig. 80, A, the width of the rectangle equals a plus b plus c. B, the height of the rectangle equals B. When three views are required, Fig. 81, A equals a plus b plus c and B equals d plus b plus e.

In some cases consideration is given to the dimensions to be

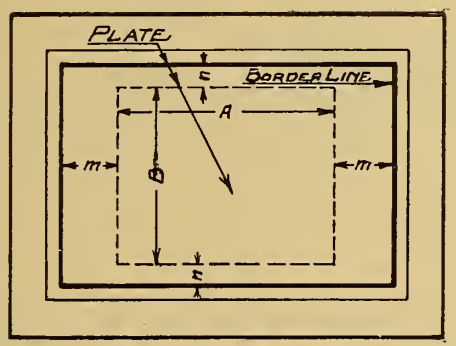


FIG. 82

placed on the several views in determining the size of the enclosing rectangle. In this course the several views are to be accurately balanced on the sheet according to the instructions here given.

(*d*) *Location of the Drawing Within the Border Line.* The required group of views is located within the border line by determining the position of the enclosing rectangle. It should be located so that m equals m and n equals n or what is the same thing B plus (2 x n) equals 10″ and A plus (2 x m) equals 14″, Fig. 82.

95. Working Methods. From what has already been said about speed and accuracy, the need of going about the work systematically is easily recognized. The system reduces to what is usually termed "drawing by stages."

(*a*) *Constructive Stage.* Under this head comes the laying out of the drawing and all instrumental penciling. In this stage all lines should be made light and full, no dotted lines being used at all. As hard a pencil should be used as the paper will permit. Lines may be drawn longer than absolutely necessary to avoid the possibility of having to patch them. Do not erase until the drawing is finished. See page 62.

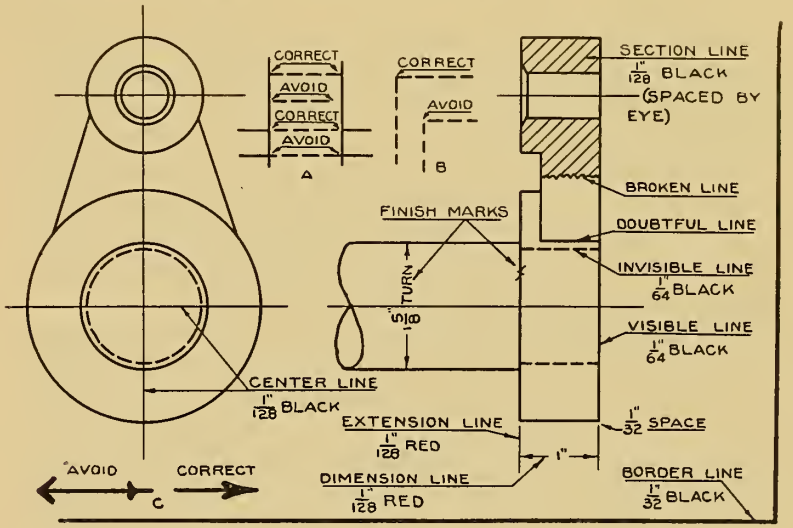


FIG. 83

(*b*) *Finishing Stage.* Go over all the lines, making them heavier and ending them at the proper points. Render all conventions. Dotted lines may now be made where required, going over the light full lines but do not try to erase between the dashes. The dashes should be all of the same length and the ends well defined. Put in extension and dimension lines, and dimensions, also notes and the title.

96. Conventions. (*a*) *Lines.* Fig. 83. A drawing in order to be clear and legible must have the different ideas involved expressed by characteristic lines. Furthermore it is very essen-

tial to the good appearance of the drawing that each class of lines be uniform in width, density and execution.

(*b*) *Object Lines.* Lines representing visible edges are full lines.

(*c*) *Invisible Lines.* Lines representing hidden edges are dash lines, the same weight as the object line, dashes $\frac{1}{8}''$ and spaces $\frac{1}{32}''$ long.

(*d*) *Dimension and Extension Lines.* Dimension lines indicate dimensions between certain limits. A full line is used. It should be broken at some point, preferably the middle, to allow putting in the dimension. In general, arrowheads are placed one at each end.

When a dimension is placed off the view, parallel lines are extended from the points between which it is to be shown, and the dimension line placed between and at right angles to them. They should begin $\frac{1}{32}''$ from the object line of which they are a continuation and end $\frac{1}{8}''$ beyond the arrow head.

97. Dimensioning. Possibly more here than anywhere in the drawing is the draftsman's best judgment called into play. It is absolutely necessary to avoid mistakes, and to facilitate the work of the mechanic, that the necessary dimensions only be given, and those placed in such a way as to make the drawing easily read and interpreted. Placing of dimensions in obscure and unexpected places should be avoided, and wherever possible they should be grouped in such a manner that their relation to each other is obvious. No doubt the best guide to follow is for the draftsman to imagine himself in the mechanic's place and consider the operations the object must go through in order to become a finished product. With this idea in mind, and a working knowledge of shop methods, which every draftsman should possess, many of the problems will be readily solved, To illustrate, when the machinst drills a hole he sets the point of the drill at the center, and hence the hole should be dimensioned by referring its center to some surface, line or point, easily accessible.

(*a*) *Form.* The general form of the dimension includes the extension and dimension lines, numeral and arrowheads.

(*b*) *To Read.* All dimensions should read from the lower and right hand edges of the drawing.

(*c*) *Notation.* Feet and inches are denoted by the signs $'$ and $''$ respectively, thus $5'-6''$ (not 5 ft. 6 ins).

(*d*) *Denomination.* Dimensions up to $2'$ are given in inches and all above in feet and inches, thus $23\frac{1}{2}''$, $2'-4''$.

(*e*) *Fractions.* Conventional fractions are used having de-

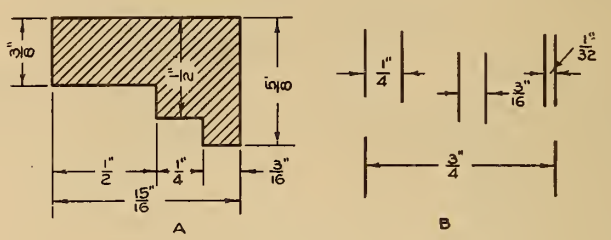


FIG. 84

nominators as shown, $\frac{1}{4}$, $\frac{1}{2}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$. Do not use such fractions as $\frac{3}{19}$, $\frac{1}{23}$, etc. For very accurate dimensions such as clearance, special fits, etc., decimals are used and are written thus- $5'' + 0.006''$, $3'' - 0.0025''$.

(*f*) *Height of Numerals and Fractions.* Use plain vertical figures $\frac{3}{32}''$ high, the numerals in both the numerator and denominator of the fraction being each $\frac{3}{32}''$ high, or the same as the whole number. Leave a small space between the numerals and division line of fraction. This adds greatly to the neat appearance.

(*g*) *The Scale* of the drawing should be placed under the title and written thus, Scale Full Size, Scale Half Size.

(*h*) *Arrangement.* Do not give the same dimension twice, nor leave them so that the workman has any calculating to do.

Judgment must be exercised in placing dimensions on or off the views. In general use the method which insures clearness.

When dimensions are grouped in paraliel lines they should be graded from the shortest on the inside to the longest outside, Fig. 84. This arrangement avoids crossing the dimension lines by the extension lines which is confusing.

Cross-hatching should be broken to allow space for numerals but not for the dimension line, Fig. 84.

PLATE 5

98. Given. The perspective view, and the front view 1 and right end view 2 in Orthographic projection, of a Planer Chuck Jaw, page 61.

99. Draw (1) A freehand sketch of the Planer Chuck Jaw

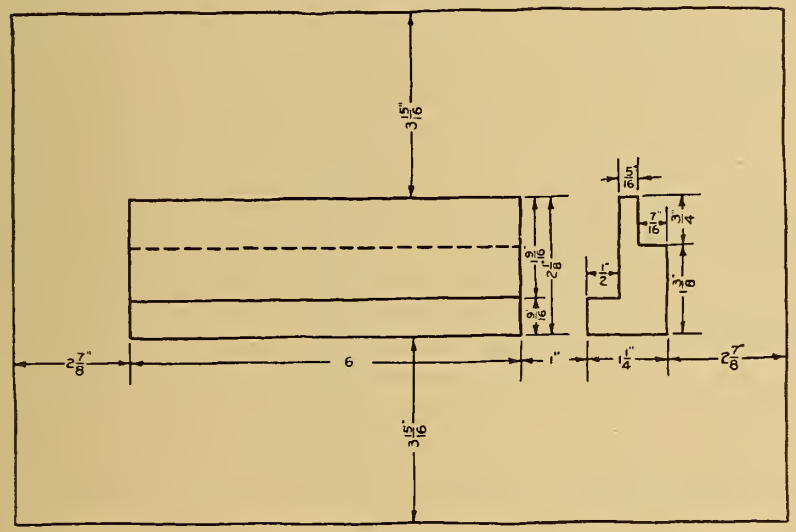


FIG. 85

similar to the one shown in Fig. 85, showing the left end view instead of the right end view. Read instructions for freehand sketching, Arts 90–93.

(2) A mechanical drawing showing front and left end view. Scale—Full size.

100. Use. The sketch represents a Planer Chuck Jaw. The chuck is bolted to the bed of the planer and holds the piece to be planed as in a vice. The Planer Chuck Jaw may be adjusted back and forth to accommodate the various sizes of the pieces to be planned.

101. Analysis of Procedure.

Lay out the border line. Art. 70.

Lay out the enclosing rectangle. Art. 94.

Lay out the views very accurately with the sixteenth scale and draw very light lines of indefinite length (be sure they are long enough) as shown on page 62.

Draw over the light lines making clear, firm lines ending them at the proper points and dotting hidden lines.

Select carefully the dimensions that are necessary for the mechanic to have in order to make the piece, and arrange them so as to show their relation to each other in the clearest possible manner. All figures should be $\frac{3}{32}''$ high; those in the fractions as well as those in the whole number. Keep the book open on the desk when putting in the figures, following carefully the general form together with the order, number and direction of strokes for each as given on pages 29-36.

The division line of the fraction should be in line with the dimension line. The figures in numerator and denominator should not touch the division line. It is a good plan to draw the division line first in the fraction. All dimensions should read from the lower and right hand edges of the sheet. Arrowheads should be about $\frac{1}{8}''$ long, the point touching the extension

line. They should be very narrow, composed of two slightly curved lines.

The pencil should be sharpened often to secure the best results. Use a 3H pencil for all freehand work. The student will in most cases need to give particular attention to the freehand work in order that it keep pace with the progress made in instrumental execution.

Extension line should start $\frac{1}{32}''$ from the object line and continue $\frac{1}{8}$ beyond the arrowhead.

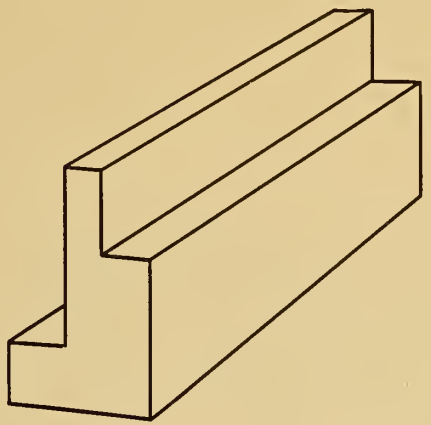
102. Title. Read Art. 84. Lay out the guide lines for the title as given on page 62. Use the following material in the order given:

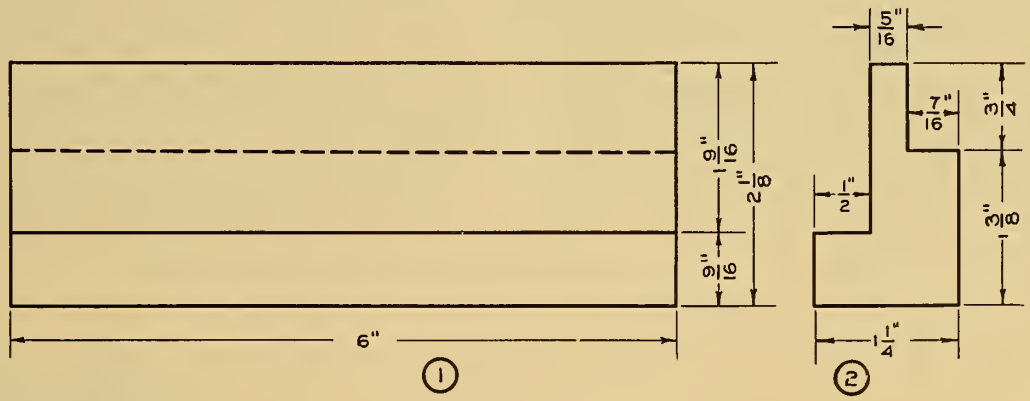
PLANER CHUCK JAW
1 WANTED–CAST IRON–FINISHED
SCALE–FULL SIZE

Print the plate number in the upper half of the filing circle and the filing number in the lower half as shown in Fig. 75A. Print the initials below the filing circle so that they are balanced on the vertical center line of the filing circle.

Print the following note in an open space near the views in letters $\frac{3}{32}''$ high.

FOR ASSEMBLY SEE DRAWING No. 3526





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COURSE I

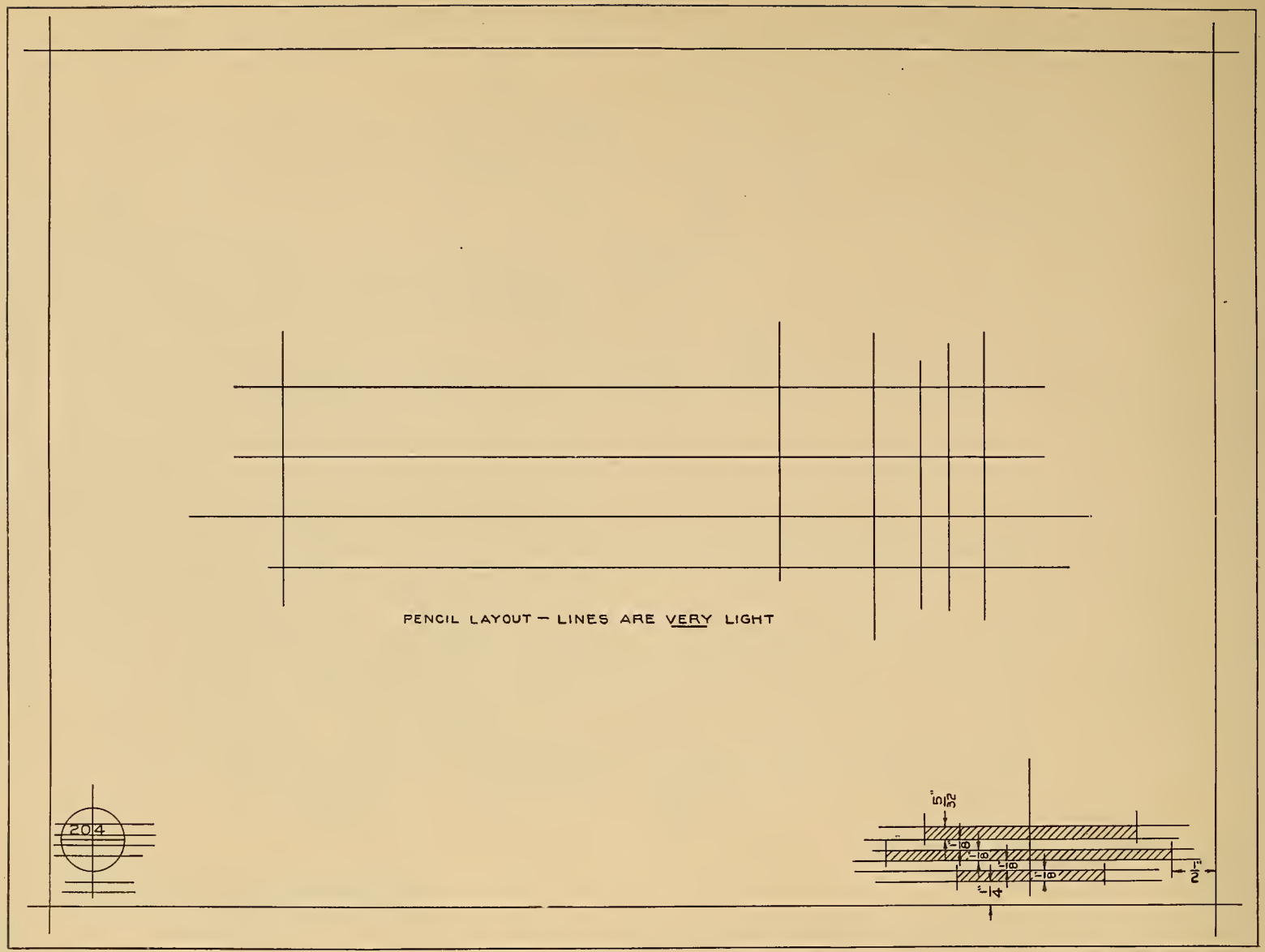

PENCIL LAYOUT — LINES ARE VERY LIGHT
204
5/32"
1/8"
1/8"
1/8"
1/8"
1/4"
1/2"

PLATE 6

TRACING OF PLATE 5.

103. Ink on the dull side of the tracing cloth. All object lines should be black and $\frac{1}{64}''$ in width. Extension and dimension lines are one-half the weight of the object lines or $\frac{1}{128}''$ (measured by eye). When ruling fine lines the pen should be frequently cleaned and refilled to secure the best results.

Freehand work should be practiced on a scrap of tracing cloth before attempting the work on the required plate. Sample letters, figures and arrowheads should be submitted to the instructors before making the drawing.

Inking is the last stage of the drawing and may be itself divided into stages. It includes the rendering of dimensions and lettering, which should come after the instrumental inking. Care should be taken to keep all lines of the same class of a uniform width. Particular attention should be given in dotted lines to make *all dashes the same length*, with both ends square and the spaces equal. Where lines meet they should run into each other, neither falling short nor running over. All corners should be perfect.

Caution—Dotted lines when ruled with the same setting of the pen as the object lines often appear heavier than the object line due to the frequent starting and stopping of the flow of ink. Especially is this true if the pen is very full. In this case the width of tho dotted line should be slightly reduced. For methods of joining lines, see A and B, Fig. 83.

Use as few dotted lines as clearness will permit.

104. Arrowheads are black, about $\frac{1}{8}''$ long. They must be made freehand with a common writing pen. They should be very slender, hugging the dimension line closely, the barbs being slightly curved, coming in tangent to the dimension line at its end.

Plate 7

SHOP DRAWING IN PENCIL. "TURRET LATHE BACK REST"

105. Note. The student's drawing is to be made from the small sketch. Fig. 87. The drawing on page 65 is similar to the one the student is to make and is given to illustrate conventions, methods of dimensioning, etc.

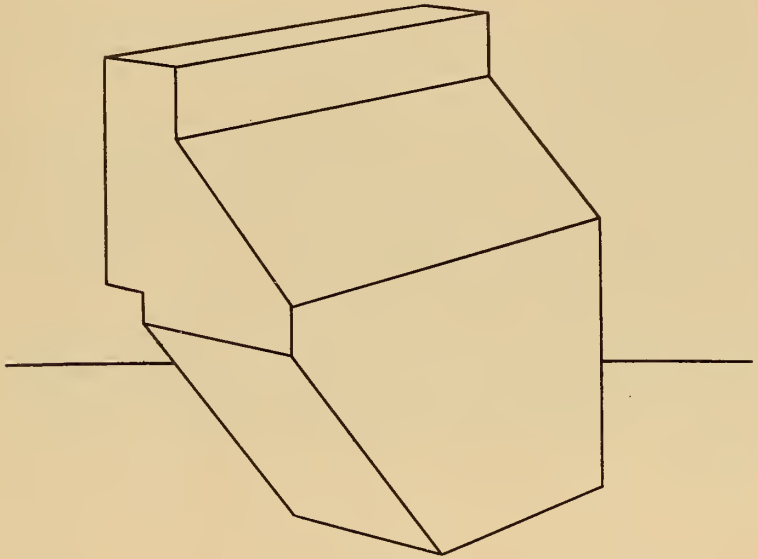


FIG. 86

Use. This piece and another similar to it form what is known as the back rest of a turret lathe. The second pierce is inverted and placed so that a 90° V is formed between the two. The revolving rod, which is being turned rests in this V, and is thus prevented from being pushed out of true by the cutting tool.

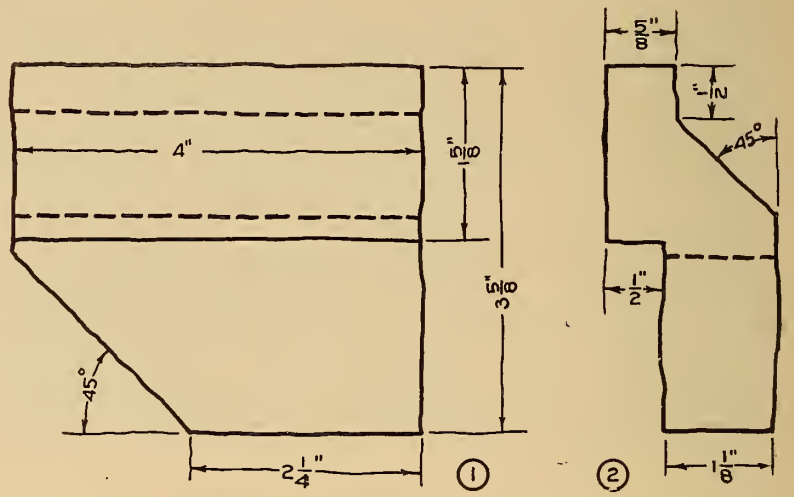


FIG. 87

106. Given. The front view 1 and right side view 2 of a "Back Rest."

107. Draw. (1) A freehand sketch as for Plate 5, showing the front and left side views.

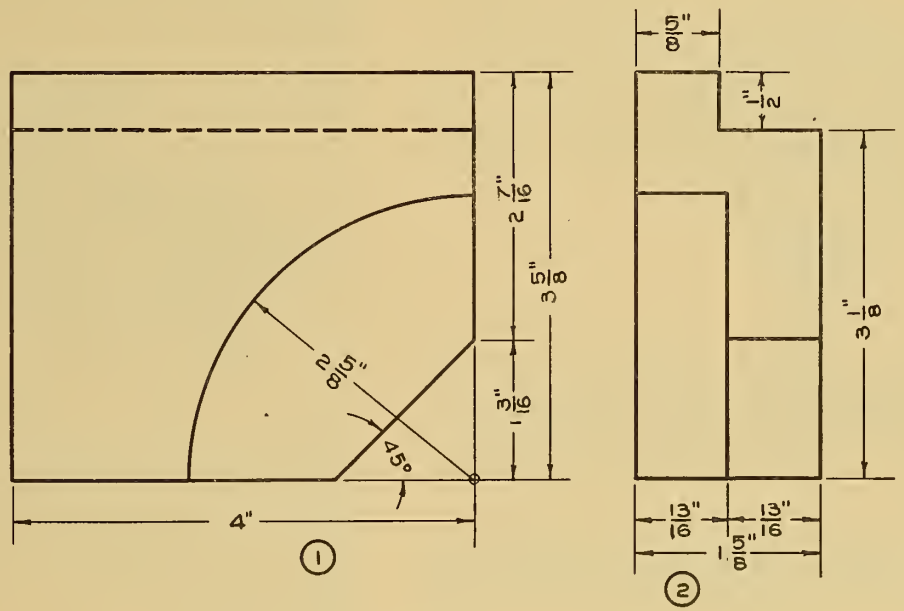
(2) A mechanical drawing showing front and left side views. Scale—Full size.

108. Analysis of Procedure.

Lay out the border line. Art. 70.

Lay out the enclosing rectangle. Art. 94.

Lay out the views very accurately with the sixteenth scale, and draw very light lines of indefinite length. (Be sure they are long enough.) Art. 95.



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COURSE I

4-11

Draw over the light lines making clear, firm lines ending them at the proper points and dotting hidden lines.

Select carefully the dimensions that are necessary for the mechanic to have in order to make the piece, and arrange them so as to show their relation to each other in the clearest possible manner. Art. 97.

Extreme care is necessary in all freehand work. All figures

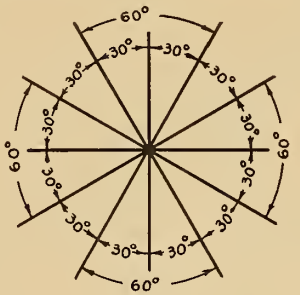


FIG. 88

must be of the same height. Arrowheads should be neat and trim. The best results are obtained by making each stroke once and once only. Do not get into the habit of working over a letter two or three times. It is sure to produce an unpleasing effect.

Refer to pages 29–36 while putting in letters and figures.

109. Conventions. *Angles* are dimensioned as shown in Fig. 88. The dimension lines are arcs with center at the vertex of the angle.

110. Title. Lay out the guide lines for the title in the lower right hand corner of the sheet according to Fig. 89. Work up the following material into the same form as given:

BACK REST
FOR
24″ TURRET LATHE
2 WANTED, 1 UPPER, 1 LOWER, UPPER DRAWN
CAST STEEL—FINISHED
SCALE—FULL SIZE

Use the method already given for balancing the title. It will insure good results and save time in the end. Art. 84.

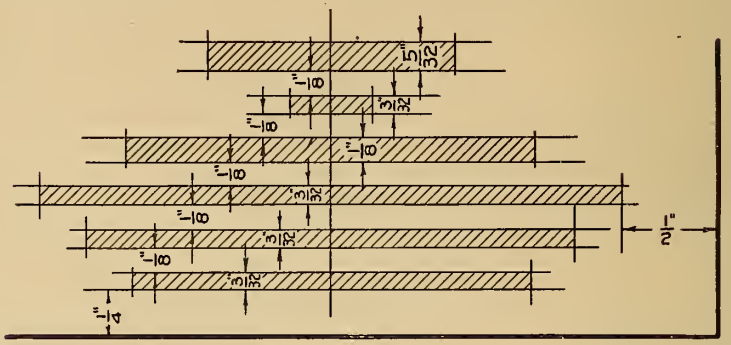


FIG. 89

Print the plate number in the upper half of the filing circle and the filing number in the lower half. Print the initials below the filing circle so that they are balanced on the vertical center line of the filing circle.

In an open space near the views, print the following notes in letters $\frac{3}{32}$″ high:

AS SHOWN PATTERN NO. 1798 U
REVERSE PATTERN NO. 1798 L

PLATE 8

TRACING OF PLATE 7

111. Read the instructions for inking given in Art. 103.

PLATE 9

SHOP DRAWING IN PENCIL. BACK BONNET FOR VALVE

112. Conventions. (*a*) *Center Lines.* A center line is used to indicate a natural axis of symmetry. A *main* center line is one about which the object or view as a whole is symmetrical, while a *secondary* center line is an axis of symmetry for part only of a view or object. The main center lines should extend about $\frac{1}{2}''$ beyond the outline of the view and the secondary center line somewhat less. Every circle has two center lines at right angles.

Center lines may be circular as in the case of a group of holes arranged on the circumference of a circle. The center line is not quite a complete circle. They may also be radial lines, as in the above case, where the other center lines of the holes are radial lines from the center of the circular center line.

(*b*) *Sectioning.* The drawing can often be made much clearer and simpler by supposing the object cut by a plane and a portion removed. One of the chief advantages is the reduction in the number of dotted lines which become confusing, when a number are necessary. Sections are usually taken by passing a plane through an axis of symmetry and parallel to one of the planes of projection. If by this process the object is divided into two similar parts the drawing is termed a *half section.* When the object is symmetrical it is often better to make a combined outside and sectional view, the division usually being made at the center line. If the two section planes are taken at right angles to each other, cutting to the axis of the object, the drawing is termed a *quarter section.*

The supposedly cut surface is conventionally represented by what is called cross-hatching, which consists of very fine parallel lines equally spaced and inclined to the horizontal. When an object consists of more than one part, adjacent surfaces belonging to the different parts are distinguished by sloping the lines to right and left respectively.

Different metals and materials may be characterized by adopting characteristic lines, spacing and inclinations, in the hatching. The most common one, cast iron, is represented by a fine full line about center line weight inclined at 45° and spaced according to the size of the surface. An average spacing is about

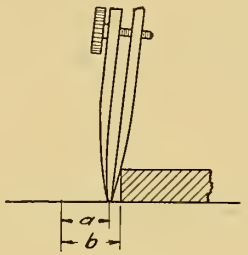


FIG. 90

$\frac{1}{16}''$. The spacing is done entirely by the eye. The student should practice on a scrap of paper so as to learn to judge the spaces correctly before attempting to work on a drawing. Unless he is very careful he will find the width of spaces changing as he proceeds, and in order to overcome that difficulty he should keep constantly comparing the one he is drawing with the first ones drawn. A common method is to estimate the distance, b, Fig. 90, from the ruling edge to the last line drawn, in doing which it is necessary to make allowance for the space taken up by the pen or pencil, thus introducing another factor of error. This may be avoided by holding the pen or pencil in position against the ruling edge so that it doesn't quite touch

he cloth or paper, and judging the space, a, from the last line drawn to the point of the pen or pencil. It is a process requiring considerable care and should not be hurried or slighted in any way, the usual penalty for which, coming as it does in the finishing stage of the drawing, is a rather troublesome erasure at least.

113. Dimensions. (*a*) *Diametral Dimensions.* Circles should be dimensioned on their diameters when possible, but never on a center line. Fig. 91.

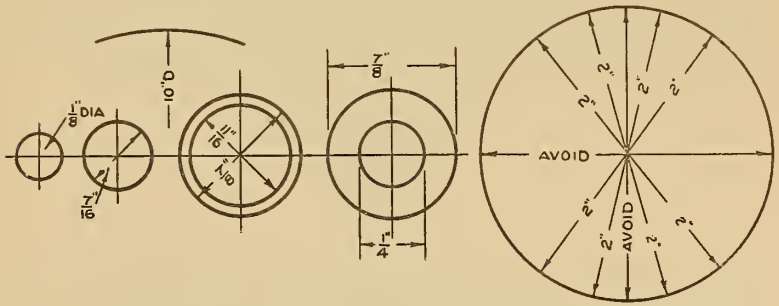


FIG. 91

When there is not room inside the circle to place the figures extension lines may be drawn out from the ends of a diameter and the figures placed outside. In case it is deemed advisable to place the diameter between parallel lines, as in the case of the side view of a cylinder, note should be made of the fact by placing DIA. or D. after the dimension.

(*b*) *Radii.* Where there is room the dimensions should be placed between the center and the arc. If for any reason the space is cramped, or in case of a cross-hatched surface with a rounded corner, the center may be ignored and the dimension placed as shown in Fig. 92. The notation R. or RAD. should be added. In case of arcs of large radius where the center is inaccessible dimension as shown.

(*c*)*Small Parts.* For various methods of dimensioning small parts where there is not room to place the figures or arrow heads, or both between the extension lines, see Fig. 84.

(*d*) *Drilled, Cored or Tapped Holes.* A hole to be drilled, cored or tapped is dimensioned conventionally by placing in a convenient space near the hole, the figures expressing its diameter followed by the word Drill, Core or Tap and underlined by a line which is bent if necessary and terminated by an arrow inside the circle. Fig. 101.

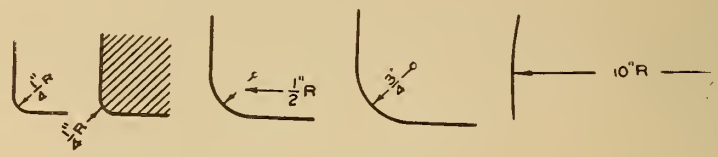


FIG. 92

When holes of the same size are symmetrically grouped, upon which the same operation is to be performed, they are dimensioned by what is turned a blanket note such as, Core 8 Holes $\frac{1}{2}''$ DIA. Drill 16 Holes 1″ DIA., 8 Holes $\frac{5}{8}''$ Tap, $1\frac{1}{2}''$ Deep.

114. Note. The instructor will assign one of the three following problems for Plate 9.

115. Conventions. View 1 of the Commutator Clamp Ring shown on page 71 is a half section. The arc of a circle drawn through the center of the holes in view 2, is a circular center line.

BACK BONNET FOR VALVE

116. Given. The perspective view of a Back Bonnet for a Corliss valve. Fig. 93.

117. Draw (1.) A freehand sketch showing the orthographic views which represent the object in the clearest manner. Do not draw unnecessary views. A half section passing through two of the one-inch holes is suggested for one of the views.

(2) A mechanical drawing showing the same views as the sketch. Scale—Half size.

118. Use. The Back Bonnet is a cover plate, which closes the opening at the rear of the valve chamber of a Corliss engine.

119. Title. Lay out the guide lines for the title in the lower right hand corner of the sheet according to the lay out given in Fig. 94.

Letter the following material arranged as given:

BACK BONNET FOR VALVE
22″ x 42″ CORLISS ENGINE
4 WANTED—CAST-IRON—FINISHED
SCALE—HALF SIZE

Print the following note near the views in letters $\frac{3}{32}''$ high.

6 HOLES EQUALLY SPACED

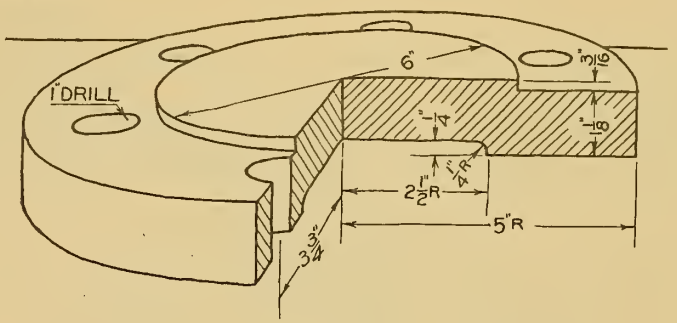


FIG. 93

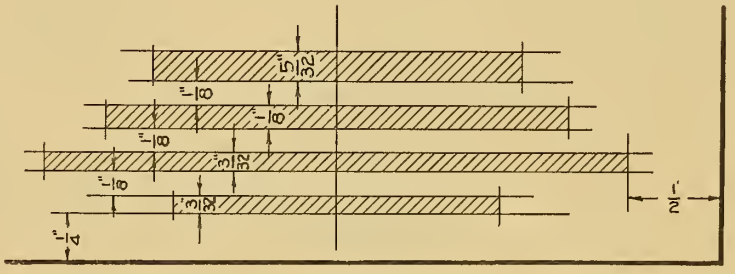


FIG. 94

FACE PLATE FOR LATHE

120. Given. The perspective view of a Face Plate for a lathe. Fig. 95.

121. Draw. (1.) A freehand sketch showing the orthographic views which represent the form of the object in the clearest manner. Do not show unnecessary views. Usually the best views are those involving the least number of hidden edges.

(2) A mechanical drawing showing the same views as the sketch. Scale—Full size.

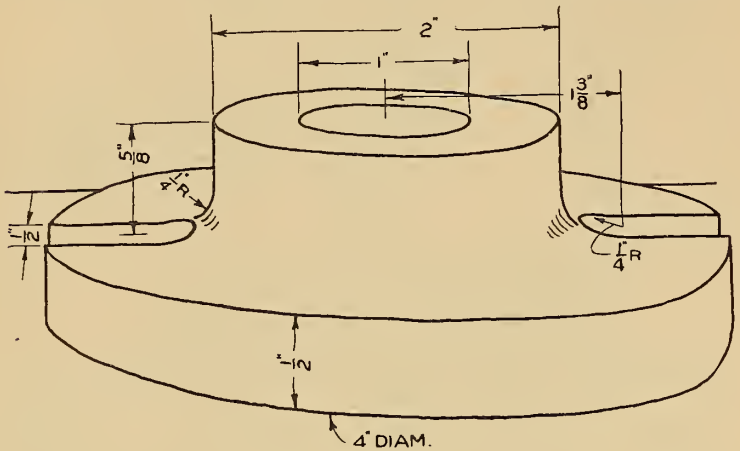


FIG. 95

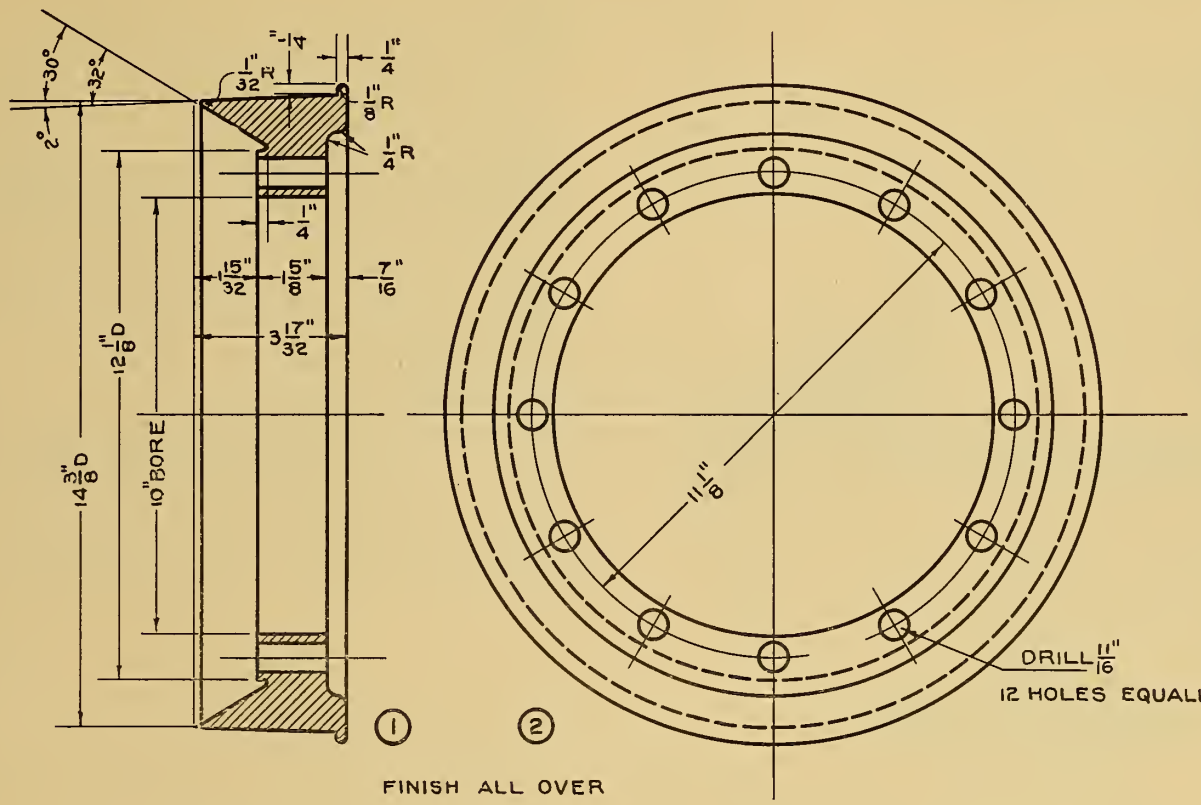
122. Use. The Face Plate is screwed to the spindle of the lathe as a nut on a bolt. The piece to be turned in the lathe is bolted to its flat face.

123. Title. Lay out the guide lines for the title in the lower right hand corner of the sheet according to the layout given on page 75.

Letter the following material as given:

FACE PLATE
FOR
ENGINE LATHE
1 WANTED—CAST-IRON—FINISHED
SCALE—FULL SIZE

Print the following note near the views in letters $\frac{3}{32}''$ high.
FOR HEAD STOCK AND SPINDLE DETAILS SEE DWGS NO. 3958 AND 3959.



FINISH ALL OVER

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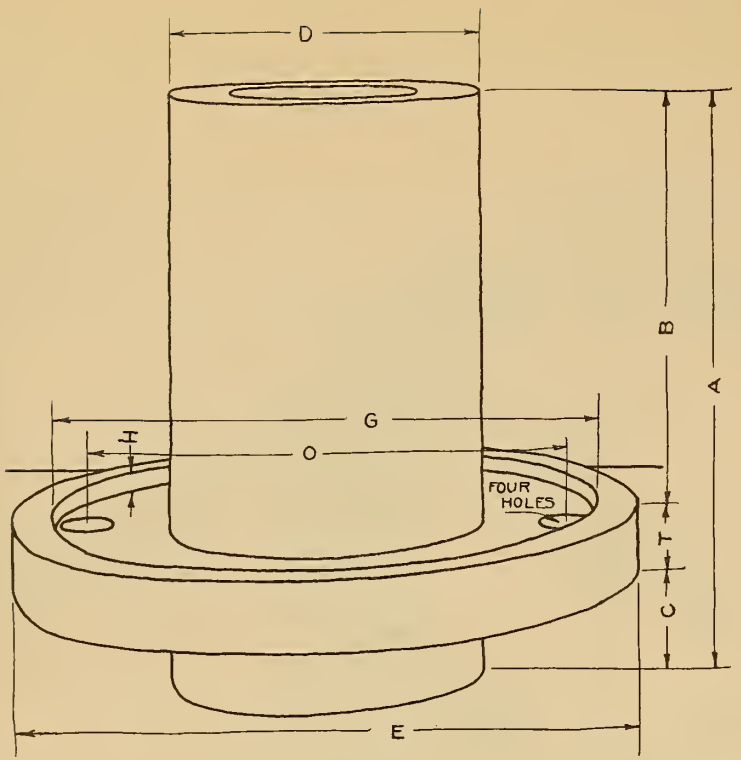


FIG. 96

DIMENSIONS IN INCHES

In Ordering Specify Pattern Number.

Shaft	Finished				Rough									Bolts		Pattern No.
	A	B	C	T	A	B	C	T	D	E	G	O	H			
$1\frac{5}{16}$	....	....	....	....	3	$2\frac{1}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$1\frac{3}{4}$	4	$3\frac{1}{2}$	3	$\frac{1}{16}$	4	$\frac{3}{8}$	R3500
$1\frac{3}{16}$	....	....	....	....	$3\frac{3}{4}$	$2\frac{5}{8}$	$1\frac{1}{16}$	$\frac{7}{16}$	$2\frac{1}{8}$	$4\frac{5}{8}$	4	$3\frac{1}{2}$	$\frac{1}{16}$	4	$\frac{3}{8}$	R3501
$1\frac{7}{16}$	....	..	....	....	$4\frac{1}{2}$	$3\frac{1}{8}$	$\frac{7}{8}$	$\frac{1}{2}$	$2\frac{1}{2}$	$5\frac{1}{4}$	$4\frac{5}{8}$	4	$\frac{1}{16}$	4	$\frac{1}{2}$	R3502
$1\frac{11}{16}$	$5\frac{1}{4}$	$3\frac{3}{4}$	$\frac{7}{8}$	$\frac{5}{8}$	...	....	....	....	$2\frac{7}{8}$	$5\frac{7}{8}$	$5\frac{1}{8}$	$4\frac{1}{2}$	$\frac{3}{16}$	4	$\frac{1}{2}$	R3503
$1\frac{15}{16}$	6	$4\frac{1}{4}$	$1\frac{1}{16}$	$\frac{11}{16}$	....	....	....	....	$3\frac{1}{4}$	$6\frac{1}{2}$	$5\frac{5}{8}$	5	$\frac{3}{16}$	4	$\frac{1}{2}$	R3504

124. Given. The perspective view of a Flanged Bearing. Fig. 96.

125. Draw. (1) A freehand sketch showing the orthographic views which best represent the object. Do not show unnecessary views.

(2.) A mechanical drawing showing the same views as the sketch.

126. This bearing is made in various sizes to suit the size of the shaft on which it is to fit. Select the dimensions from the table for the shaft, which will make the drawing of a convenient size, but dimension the drawing with the symbols. Leave a space on the sheet in which to print the table as given. The bolt holes should be about $\frac{1}{32}''$ larger than diameter of the bolt to allow for the clearance.

127. Title. Letter the following words $\frac{5}{32}''$ high in the lower right hand corner of the sheet.

FLANGED BEARINGS

PLATE 10

TRACING OF PLATE 9

128. The work of inking may be divided into steps as follows, beginning at the upper left hand corner and working downward and to the right: (1) Draw all circles and arcs, the smaller ones first and all of the same radius at one setting of the compass. (2) Ink vertical lines. (3) Ink all horizontal and other straight lines. (4) Render the dimensions. (5) Put in screw thread conventions, show breaks and cross hatch sections. (6) Put in the title and ink the border line.

129. Center lines are full black lines and about $\frac{1}{2}$ the weight of the object line or $\frac{1}{128}$ in. in width.

PLATE 11

SHOP DRAWING IN PENCIL. "STUFFING BOX GLAND"

130. Conventions. View 1 of the gland shown on page 76, illustrates the quarter section. Read Art. 112b.

Especial attention is called to the fact that there is an object line across the middle of the section view representing the edge of the lower half of the object, which is the result of the horizontal cut.

Note the method of dimensioning the arc of $\frac{5}{8}''$ radius on sheet.

To insure accuracy points of tangency are located exactly by the method illustrated in Fig. 97. A triangle a is placed with its edge along the tangent line as shown in dotted lines, a second triangle b is placed against the first and held stationary while the first is revolved into the second position in which one edge is perpendicular to the tangent line and passes through the center of the arc. According to the laws of geometry the foot of the radius perpendicular to the tangent line is the point of tangency. The point of tangency should be located by a short mark as shown at c. The lines marking the points a of tangency should be left as a guide in inking but should not be traced.

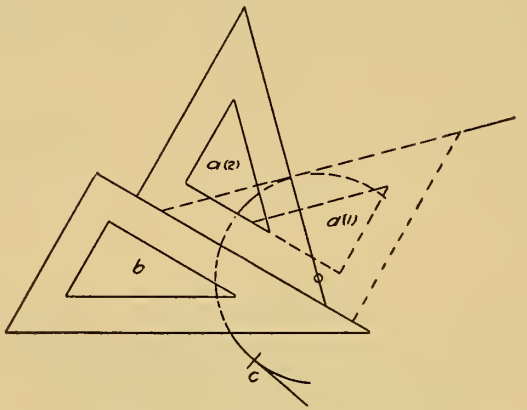


FIG. 97

131. Given. The perspective view of a Stuffing Box Gland. Fig. 98.

132. Draw (1.) A freehand sketch showing the orthographic views which will best represent the object. It is suggested that one of the views be a quarter section view.

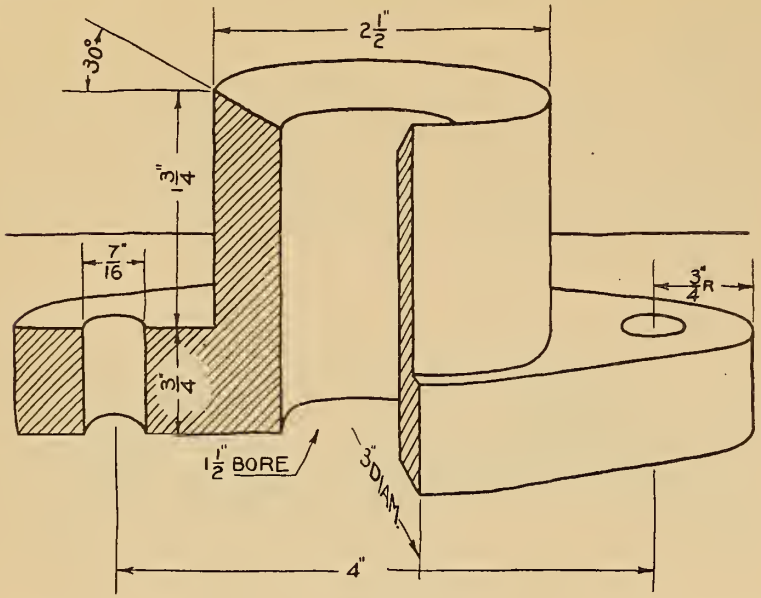


FIG. 98

(2.) A mechanical drawing from the sketch. Scale — Full size.

133. Use. The gland is the piece which fits around the piston or valve rod, and when forced into the stuffing box, compresses the packing thus forcing the packing against the rod and making a steam tight joint as the rod moves into and out of the cylinder or steam chest.

134. Analysis of Procedure. The original pencil layout for this sheet will look like that on page 75, that is all lines including the circular arcs are drawn longer than necessary and are as light as possible. The arcs are drawn first and the tangent lines drawn by placing a straight edge so that a line ruled along it will just touch the arcs.

135. Title. Use the layout for the title on page 75 and the material given below.

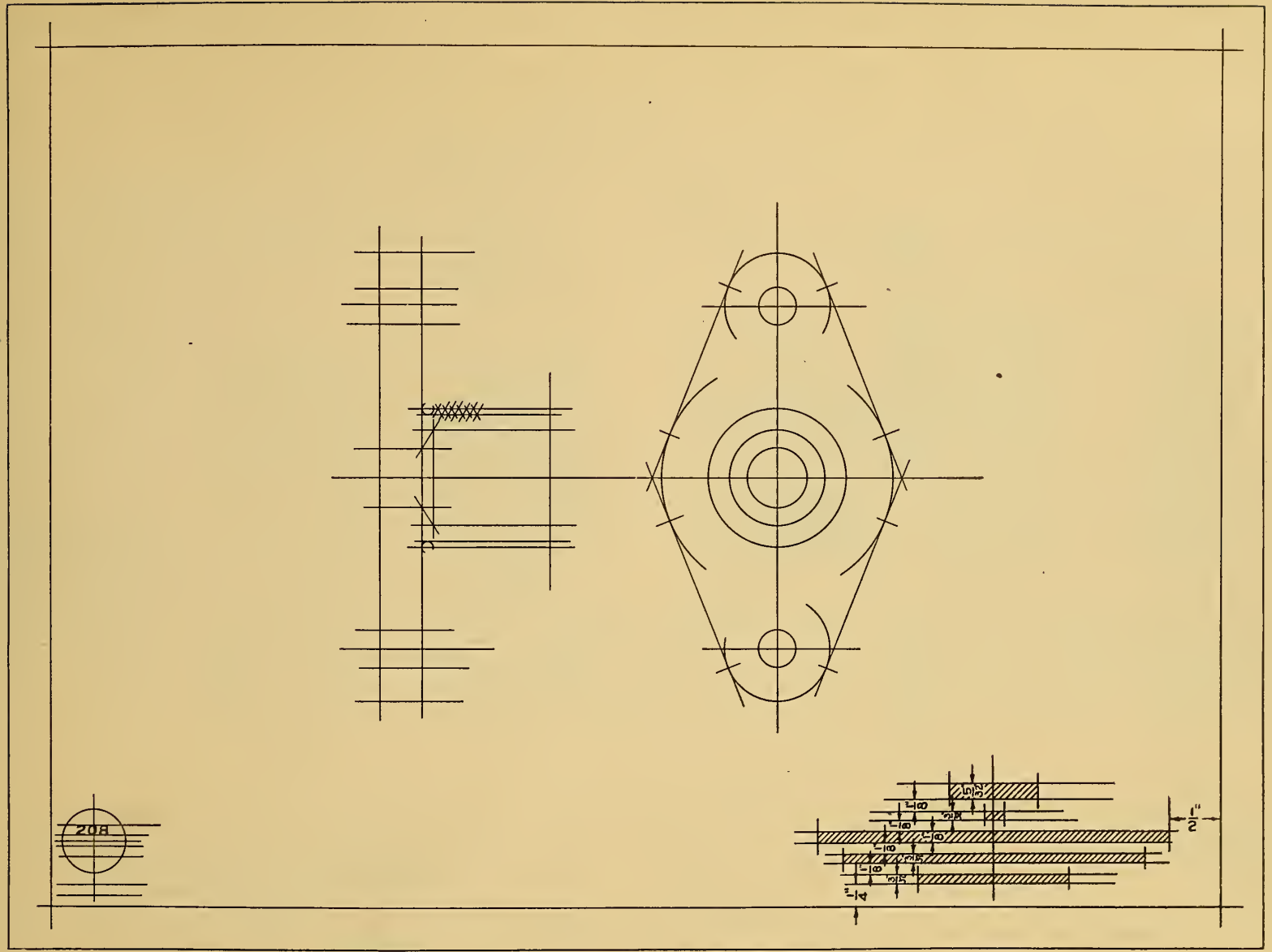
GLAND
FOR
THROTTLE VALVE STUFFING BOX
1 WANTED—CAST-IRON—FINISHED
SCALE—FULL SIZE

Fill in the filing circle as usual.

PLATE 12

TRACING OF PLATE 11

136. Read carefully Art. 128. It is essential that the arcs be drawn first, stopping them exactly at the points of tangency to insure good joints. The points of tangency should be located in pencil on the tracing cloth. Art. 130.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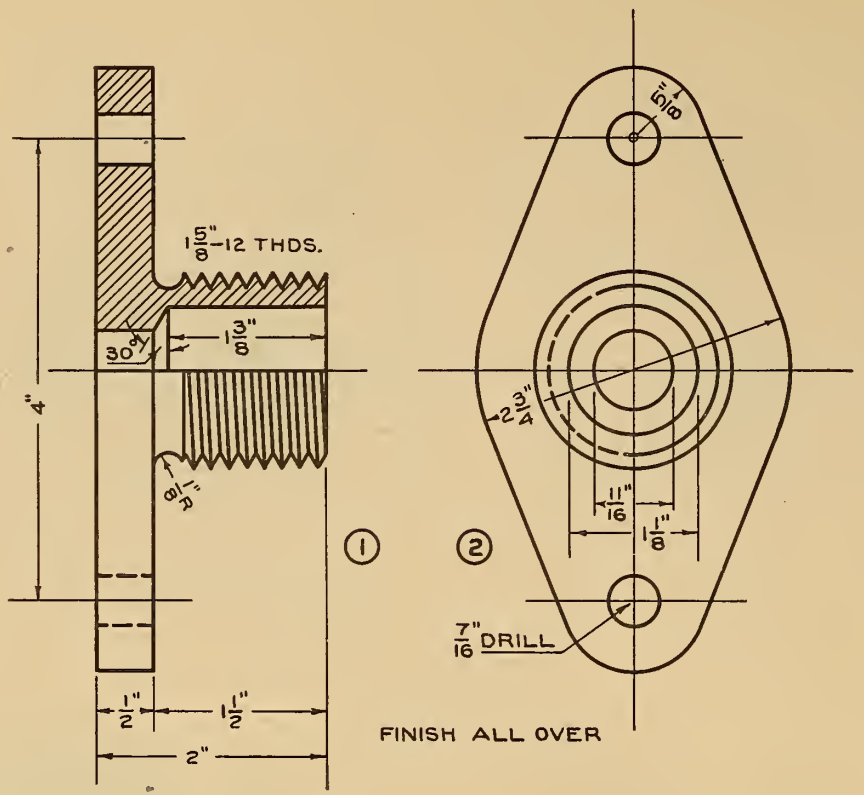

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PLATE 13

SHOP DRAWING IN PENCIL. BRACKET

137. Conventions. (1) *Screw Threads* are based on the curve which is known as the helix. Fig. 99 A. It is generated by a point which moves on the surface of a cylinder with a uniform motion parallel to the axis and at the same time rotates about the axis with a uniform motion. The distance traversed by a point parallel to the axis in one revolution is called the pitch. In the case of threads this is the distance measured parallel to the axis between corresponding points on two successive threads.

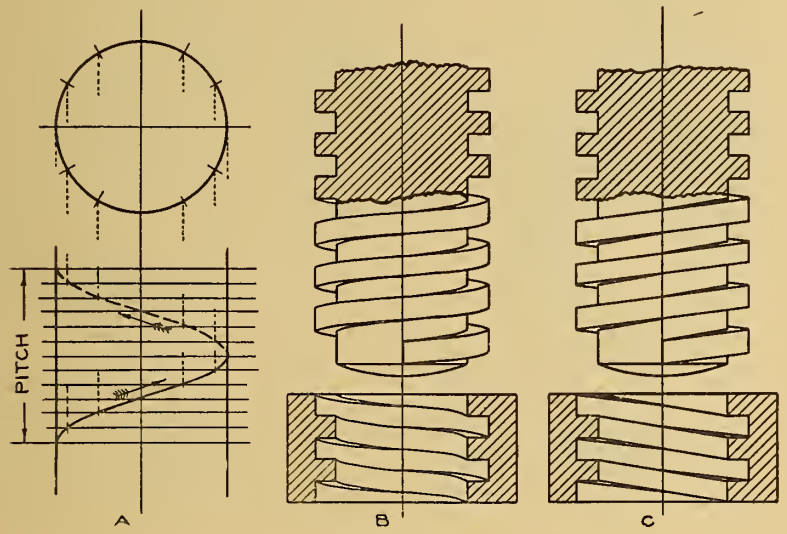


FIG. 99

Square Thread. Fig. 99 B, shows the projection of a right square thread. Fig. 99 C, shows the conventional representation of a right square thread where the curves are replaced by straight lines.

V Thread. Fig. 100 A, is the projection of a V thread. B and C, Fig. 100, are conventional represention of the V thread.

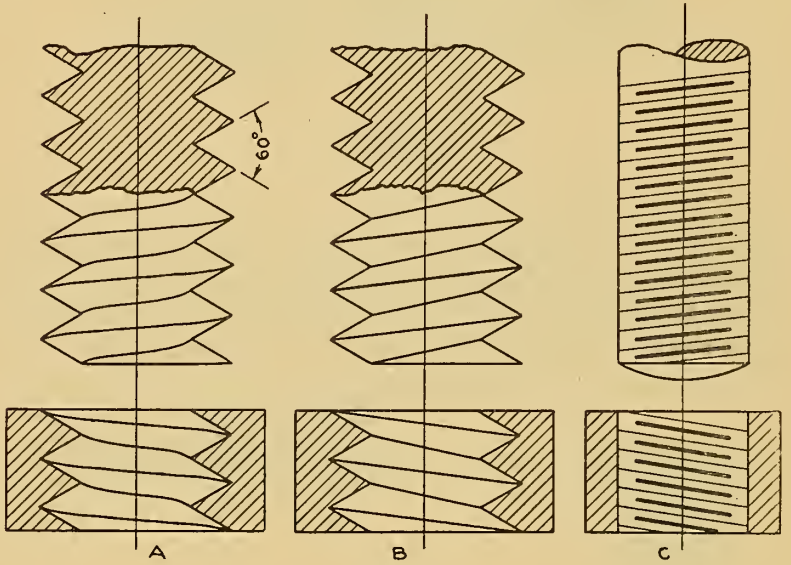


FIG. 100

B is sometimes used when the drawing is made to large scale or for exhibition purposes, but C is used in common practice. C is arrived at by first making the curved lines straight and then omitting the short lines forming the saw edge.

Methods of representing the side, section and end views of tapped holes and bolts are shown at B and C, Fig. 101. These

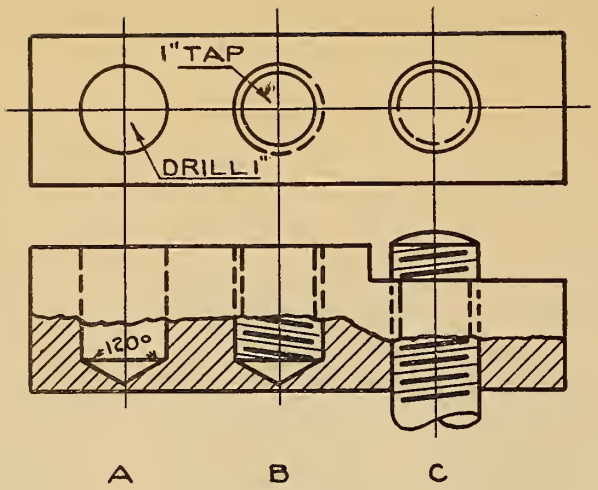


FIG. 101

should be carefully studied and kept in mind for future use. Note that the inclination of the threads in the section of the tapped hole is opposite to that of the bolt which fits it.

The Pipe Thread is illustrated in Fig. 102. In order to insure tight joints the threaded portion tapers as shown. The first four

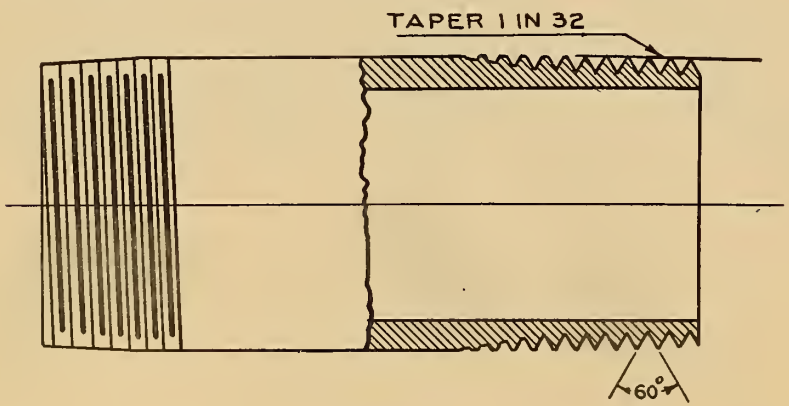


FIG. 102

threads at the left (sectional portion), are imperfect at the top and root, the next two are imperfect at the top only, and all to the right of these are full threads.

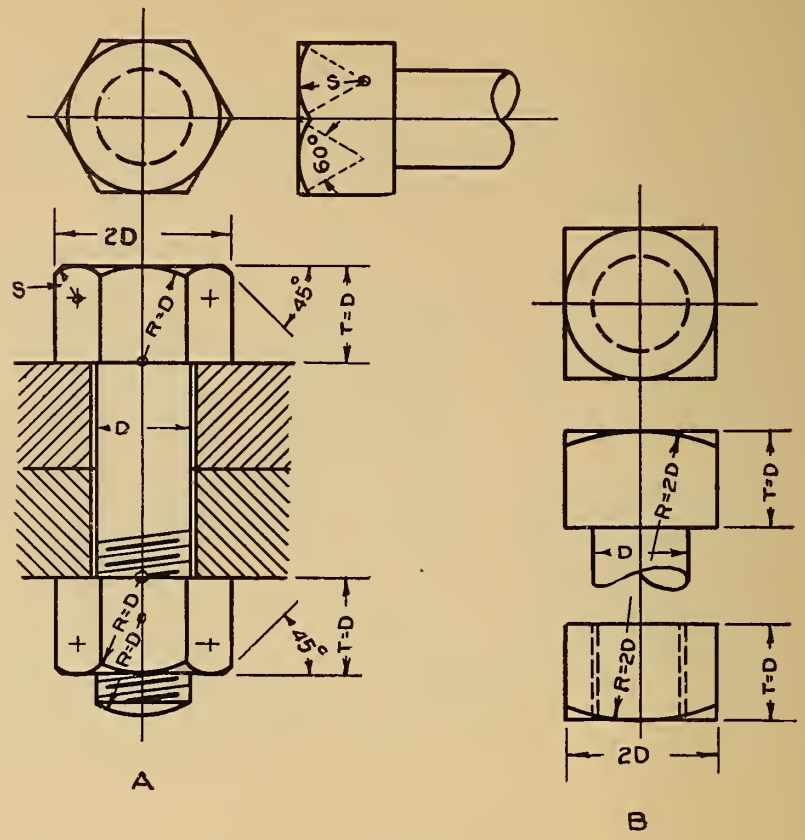


FIG. 103

Bolts. Fig. 103 A and B, give the proportions for drawing hexagonal head and square head bolts. These proportions do not correspond to the actual dimensions. See a table of bolt and nut sizes for actual sizes.

A Stud. Fig. 104 A, is a rod of metal threaded at both ends, and is used for fastening on such things as cylinder heads. The figure illustrates the method of its application.

A Cap Screw. Fig. 104 B is a rod of metal with a head at

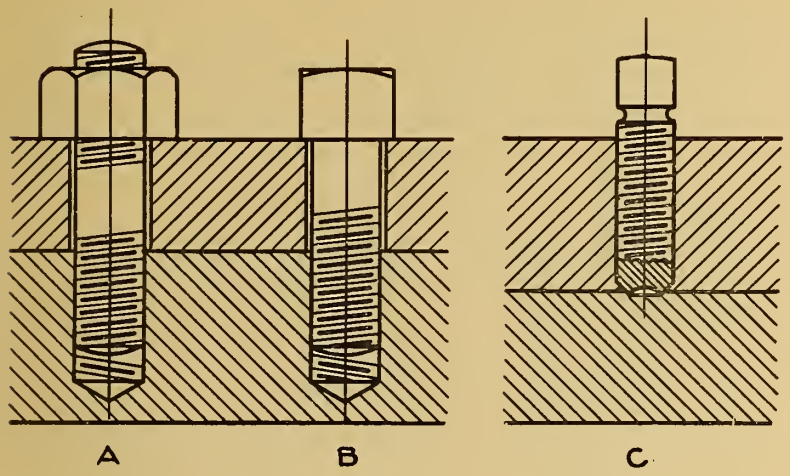


FIG. 104

one end aud threaded at the other for about two-thirds of its length.

Machine screws are similar to cap screws, and are used for like purposes, but usually for smaller work. The main point of difference is that cap screws are measured in inches, while machine screws are designated by a machine screw gage. Both have heads of various shapes.

Set Screw. Fig. 104 C shows a set screw. Its function is to prevent relative motion of the two parts which are held in contact by some other means, as, for instance, a shaft in the hub of a pulley.

138. *Centers* for rounded corners, fillets and other arcs which do not have their centers on any line of the drawing are located

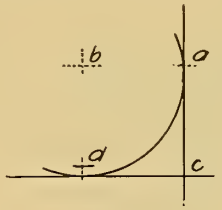


FIG. 105

by what is called the "trial and error" method. First adjust the compass to the proper radius, then set the lead on the tangent line at a, Fig. 105, making ac as nearly as possibly equal to the radius (by eye). Set the needle point opposite a and bring the lead around to d. Move the needle point parallel to ac an amount equal to the error.

139. *Broken Lines.* Where it is desired to show a broken edge a ragged line is drawn, with a writing pen, of about the same weight as the object line.

PLATE 13

140. Given. The front view, 1, the end view, 2, section on AA, 3, and the true outline of the flanges 4. Fig. 107.

141. Draw (1.) A freehand sketch showing a shop solution, i. e., a solution in which the plotting of points is avoided by the use of auxiliary views.

(2.) A mechanical drawing from the sketch. Scale—Full size.

142. Use. The bracket is that part of a drill grinder which serves to support the V shaped holder into which the drill is placed for grinding. The cylindrical part whose axis is hori-

zontal fits over and is clamped to a cylindrical projection from the frame of the machine. A cylindrical projection on the tool holder mentioned above fits into the inclined hole and is clamped

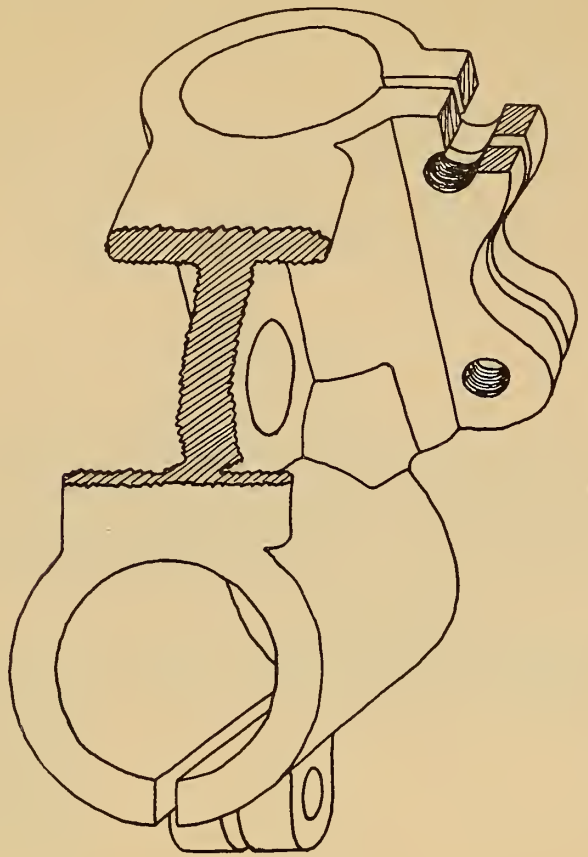


Fig. 106

just tight enough so that it may turn without jarring when the machine is in operation.

143. Dimensioning. The arrangement of dimensions on the sketch given is not the best, and in view of the fact that additional or different views are necessary in the solution, the student will need to exercise his judgment in the disposition of dimensions so as to make the drawing read as clearly and easily as possible.

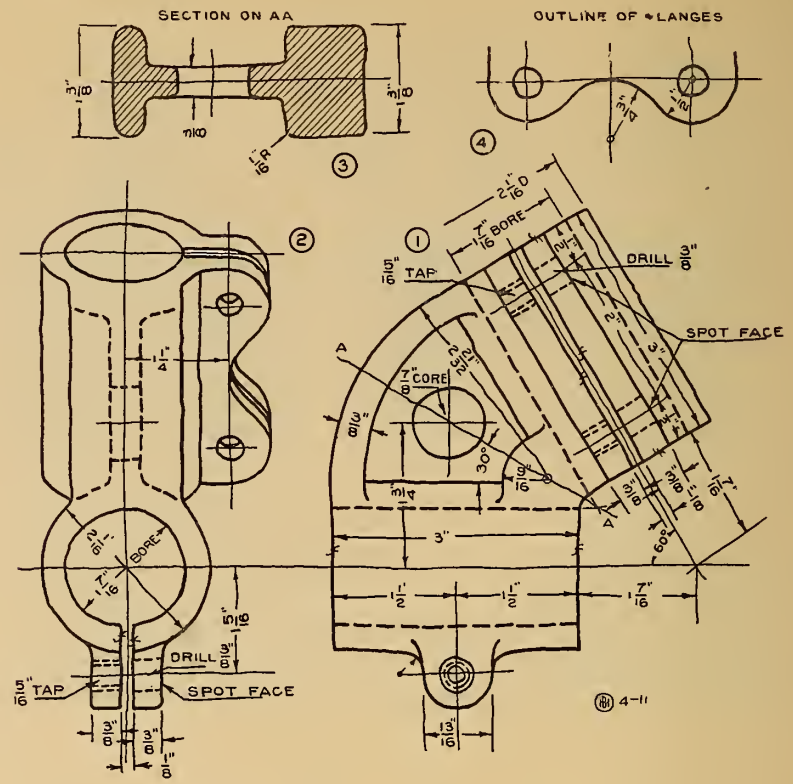


Fig. 107

As far as possible the dimensions for the section should be placed on the section rather than on the other views.

The $\frac{7}{8}''$ hole in the web which joins the two cylindrical parts should be marked "core" as it is made by a core of sand in casting.

The $\frac{1}{8}''$ slots should be cut with a $\frac{1}{8}''$ milling cutter and note should be made to that effect in connection with the dimension.

The surface on which the heads of the studs will rest should be finished, and as it is only necessary to finish these spots, the operation should be noted by marking them "spot face."

In the solution of this problem it will be necessary to give some partial views, i. e., views which only show part of the object. In a case of this kind where it is necessary to consider part of the object broken away, a ragged line is drawn, with the writing pen, across where the break occurs.

When a section of some part of the object is shown in a separate view, a line should be drawn where the plane of the section cuts the object and labeled, as for instance, AA, a note being made near the section view "section on AA."

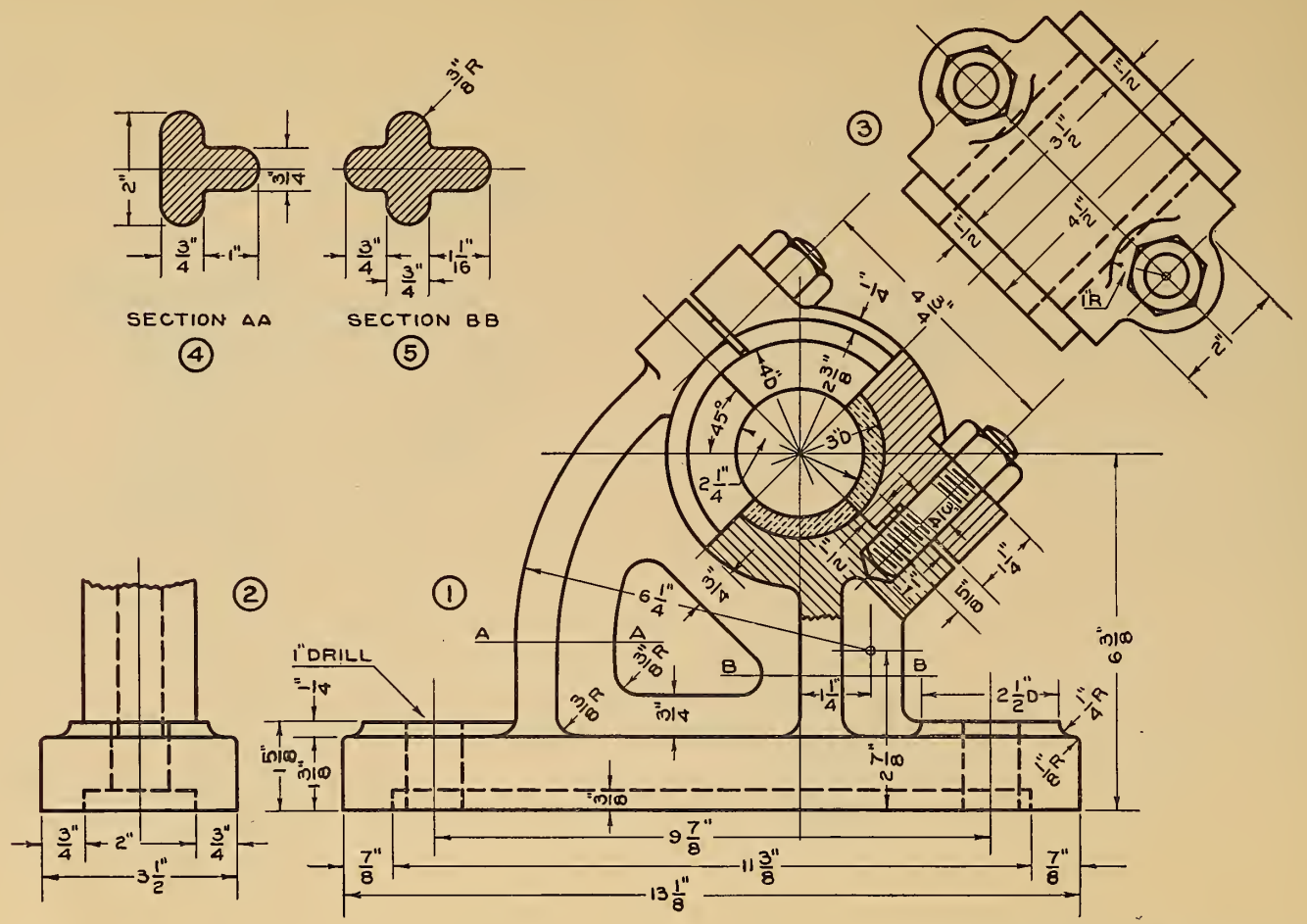
All of the surfaces of this object are not to be finished and consequently the word "finished' must be omitted from the title. Those surfaces which are to be finished are marked in the view where they show as a line with an *f* as in Fig. 107, or the finish is indicated in some other way, such as by printing the word "bore," "turn," etc., with the dimension on a diameter.

144. Title. Use the title layout given on page 75 and the material given below.

DRILL REST BRACKET
FOR
YANKEE DRILL GRINDER
1 WANTED CAST IRON
SCALE FULL SIZE

PLATE 14

TRACING OF PLATE 13



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DEPARTMENT OF DRAWING
COURSE 1

PLATE 15

SHOP DRAWING IN PENCIL.—"CHECK WASHER"

145. Given. The front view 1, and auxiliary view 2. Fig. 108.

146. Draw. The front, auxiliary and top views. Scale—Full size.

147. Use. A washer of this kind is used in wooden roof trusses. Its function is to furnish a flat bearing for the head of a bolt which passes obliquely through a timber. The lugs on the under side are let into the wood to prevent it from sliding.

148. Title. Use the layout given for Plate 11.

CHECK WASHER
FOR
WOODEN ROOF TRUSS
24 WANTED—CAST-IRON
SCALE—FULL SIZE

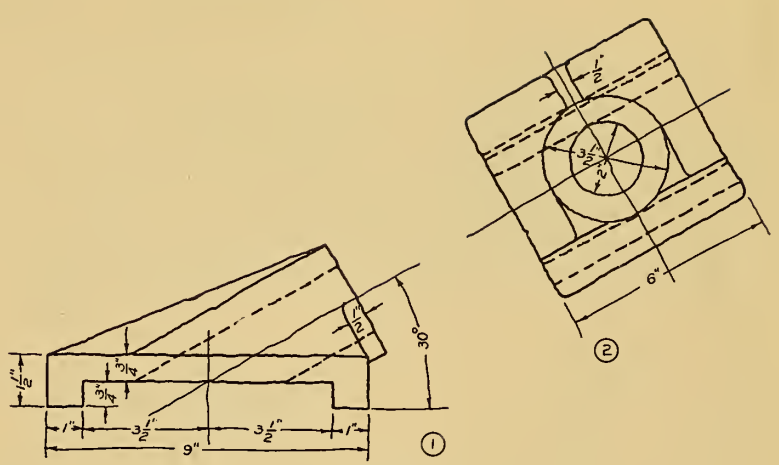
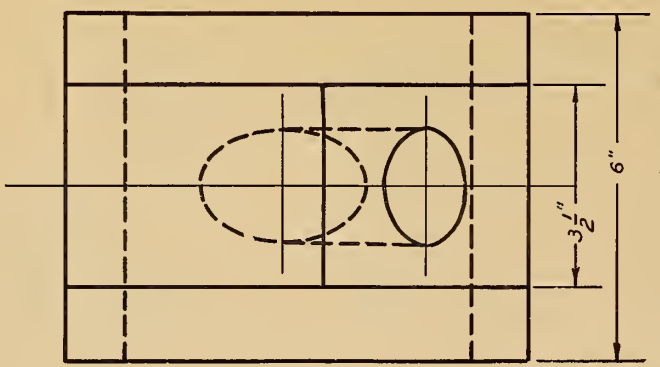


FIG. 108

PLATE 16

TRACING OF PLATE 15



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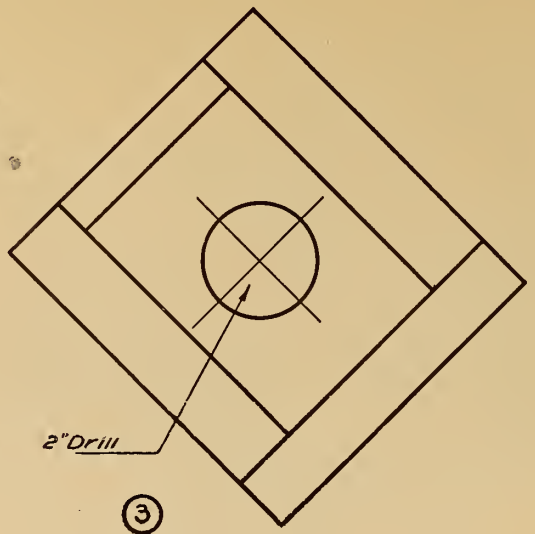
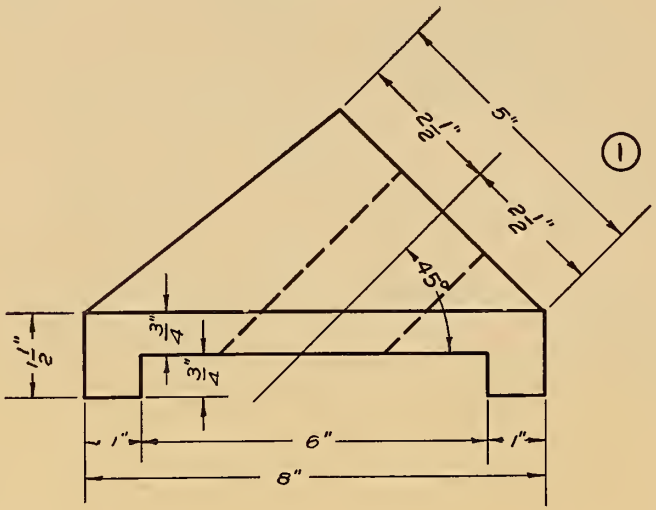


3



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UNIVERSITY OF WISCONSIN
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COURSE 2

CHAPTER 4

ISOMETRIC AND CABINET PROJECTION

149. Isometric Projection is a method of representing an object in one view. This view shows more than one face of an object thus giving the effect of a picture. Because the theory involved is much simpler and its application is much easier this method is often preferable to the exact pictorial representation afforded by perspective. An isometric drawing of an object is

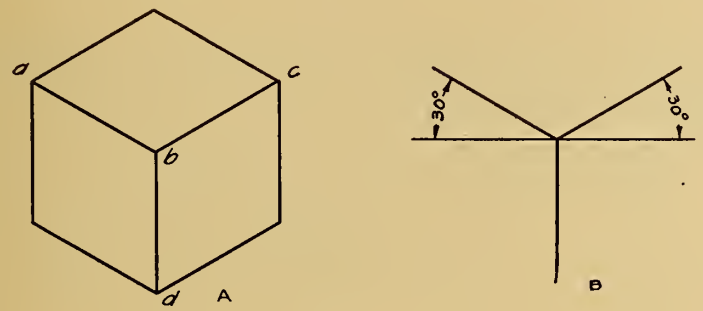

FIG. 109

usually termed the "isometric" of the object. Isometric is used for illustrating parts of machines or structures where the orthographic is hard to read, or for those who are unaccustomed to reading working drawings. It is also used in patent office drawing.

150. Derivation of Axes. If a cube is placed so that one of its diagonals is perpendicular to a plane of projection, the projection of the cube upon the plane will appear as in Fig. 109 A. The projections of the three nearest edges of the cube **a b, b c and b d** make equal angles with each other (120°).

Under the conditions stated the edges of the cube all make the same angle with the plane of projection. There projections are, therefore, all foreshortened in the same ratio. This foreshortening is generally disregarded, and the lines made actual lengths in the drawing. The only effect of this is to change the scale of the drawing.

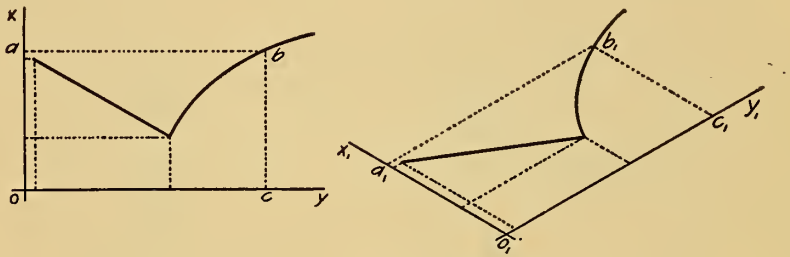

FIG. 110

It has been stated that the cube was placed with a diagonal perpendicular to the plane of projection. Its position is further limited by turning it about this diagonal until the projections of two of the near edges make 30° with a horizontal line, while the third is vertical. Fig. 109 B. These three lines represent the dimensions of the cube, and consequently its isometric may be drawn by laying off lengths parallel to these lines. They are called the isometric axes.

The following is a summary of the underlying principles of isometric drawing.

(*a*) *The axes represent three lines mutually at right angles, thus corresponding in length, breadth and height. All measurements on the drawing must be laid off parallel to these axes.*

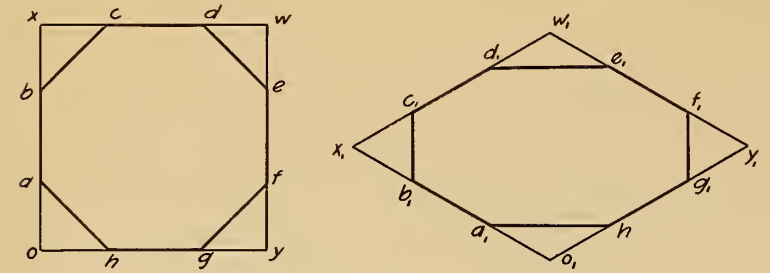

FIG. 111

(*b*) *Parallel lines in the object are parallel in the drawing. Vertical lines are drawn vertical.*

151. Non-isometric Lines. Lines of the object which

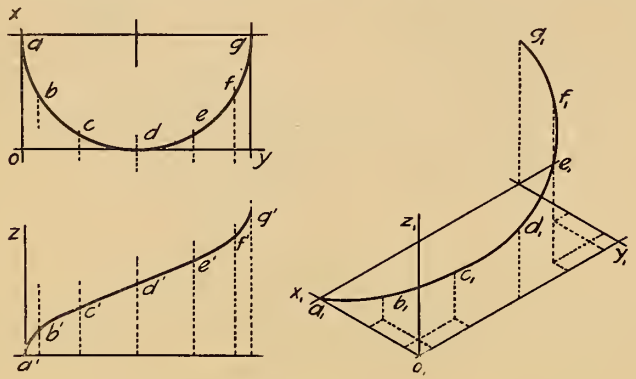

FIG. 112

cannot be drawn parallel to one of the three axes are termed non-isometric lines. Such lines must be drawn by co-ordinates taken parallel to the axes as shown in Fig. 110.

(*a*) The work of laying out non-rectangular plane figures may be simplified if they can be inscribed in rectangles. Fig. 111.

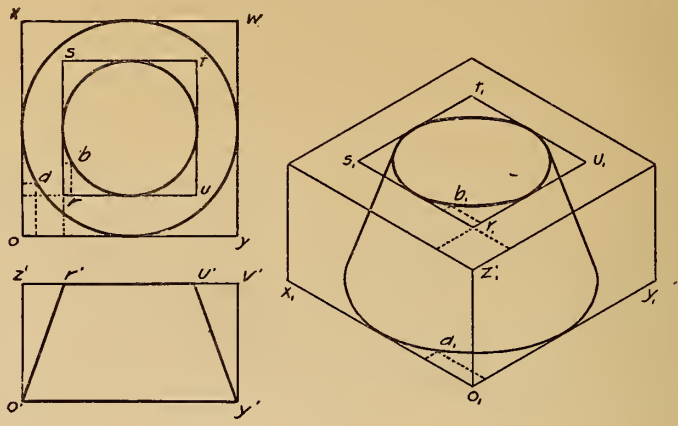

FIG. 113

(b) *Three dimension figures* may be laid out in a manner similar to that shown for plane figures by introducing a third co-ordinate. Fig. 112.

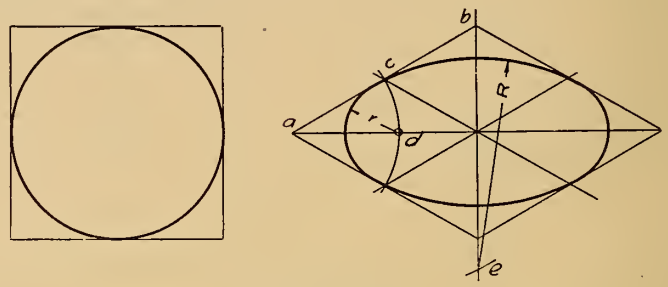

FIG. 114

(*c*) *Non-rectangular solids* which can be inscribed in a rectangular prism may be drawn as in Fig. 113.

152. Approximate Isometric Circles. Circles may be drawn more easily, though not so accurately, by the following method. Draw first the isometric of the square circumscribing

the circle. The center **d**, Fig. 114, for the short radius **r** is found by striking an arc with center at **a** and radius **ac** = $\frac{1}{2}$ **ab**, **r** = **dc**. The center of the long radius **R** is located by striking an arc with its center at **c** with radius = **ab**, **R** = **ec** = **ab**.

153. Cabinet Projection. The uses and fundamental principles are very similar to Isometric Projection. Fig. 115. Here one face of the object is parallel to the plane of projection. There are three axes, one horizontal, one vertical and one at 45°. Actual lengths are laid off parallel to the horizontal and vertical axes. One-half actual lengths are laid out parallel to the 45° axis. Circles in planes parallel to the plane of projection show as true circles. All others must be plotted.

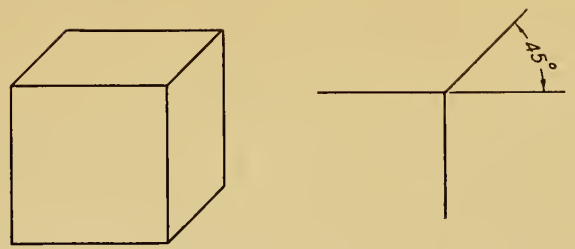

Fig. 115

Plate 17

154. Made an isometric and a cabinet drawing of the pyramid described in the following problem. Place the top and front views in the middle of the sheet in orthographic projection. To the right of this draw the cabinet and to the left the isometric. Ink in the drawing on the paper.

155. Title. Beneath each view print the name corresponding: Isometric, Orthographic and Cabinet in vertical capitals $\frac{5}{32}''$ high.

156. Draw. A hexagonal pyramid $3\frac{1}{2}''$ high; side of hexagonal base $1\frac{1}{4}''$ long. Half way up the sides of the pyramid is a groove extending entirely around the pyramid. This groove is formed by removing the portion of the pyramid between two cuts, each $\frac{1}{4}''$ deep (measured parallel to the plane of the cut and perpendicular to the edge of the hexagon). The planes of both cuts are parallel to the planes of the base of the pyramid. The perpendicular distance between the planes of the two cuts is $1''$. (From Tracy's Mechanical Drawing.)

PLATE 18

157. Make a working drawing of a wooden box. Scale—

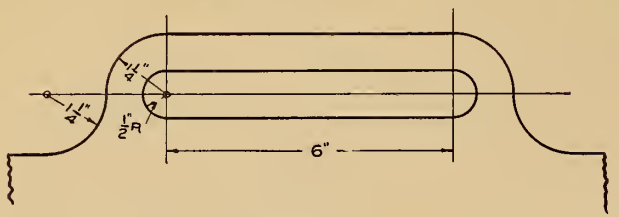

FIG. 116

Half size. The top of the box is 10″ x 16″ OA (over all), bottom $8\frac{1}{2}$ x $12\frac{1}{2}$″ OA; depth 3″ OA. Opposite sides have the same slope. The bottom board laps over the sides and the sides lap over the ends. Thickness of material $\frac{1}{2}$″. A vertical partition which is parallel to the longer edges divides the box into two equal compartments. The upper part of this partition is cut into the form of a handle as shown in Fig. 116. Show all dimensions. Ink on paper.

A note should be printed on the drawing in inclined lower case letters as follows,—Hard wood—all joints glued and nailed —thickness of material $\frac{1}{2}$″.

158. Title.

TOOL TRAY
SCALE—HALF SIZE

PLATE 19

159. Make an isometric of the box in Plate 18. Copy the note and title. Show all dimensions. Ink on paper.